Green Gas
OIL & GAS TECHNOLOGY

LPG

BASIC PRINCIPLES AND PRACTICES

One\ LPG physical and chemical properties

Two \ LPG System components

- LP gas Tanks
  - Codes of Design & Manufacturing , ASME versus EN
- Regulators
  - 1st Stage & 2nd Stage regulators.
- Vaporizers
  - Direct Fire
  - Electrical
- Safety Equipment

Three \ Design Elements of LP-Gas System

Introduction to the international standards and codes regarding the use of gas. (NFPA 58 \ NFPA 54 \ Gas Transmission pipe lines) in term of:

- Container Locations & preparations.
- Cylinder & Tank Manifolding
- Pipe Selection
- Pipe Sizing
- Regulator selection
- 2 Stage Regulation
- Safety Precautions and measures including safety equipment and accessories.(anti seismic valves, excess flow , fused , solenoid valves, gas leakage detectors, change over panels, gas meters, relief valves)
- Testing methods

Four \ Natural Gas Vs. LPG , applications and characteristics

- NG \ SNG \ LPG & the wobbe Index
- Shaving systems & LPG - Air mixers
- Cost analysis for several types of fuel (Diesel , LPG, NG & SNG)

Five \ Designing complete LPG \ SNG \ NG system – Case Study & site visit

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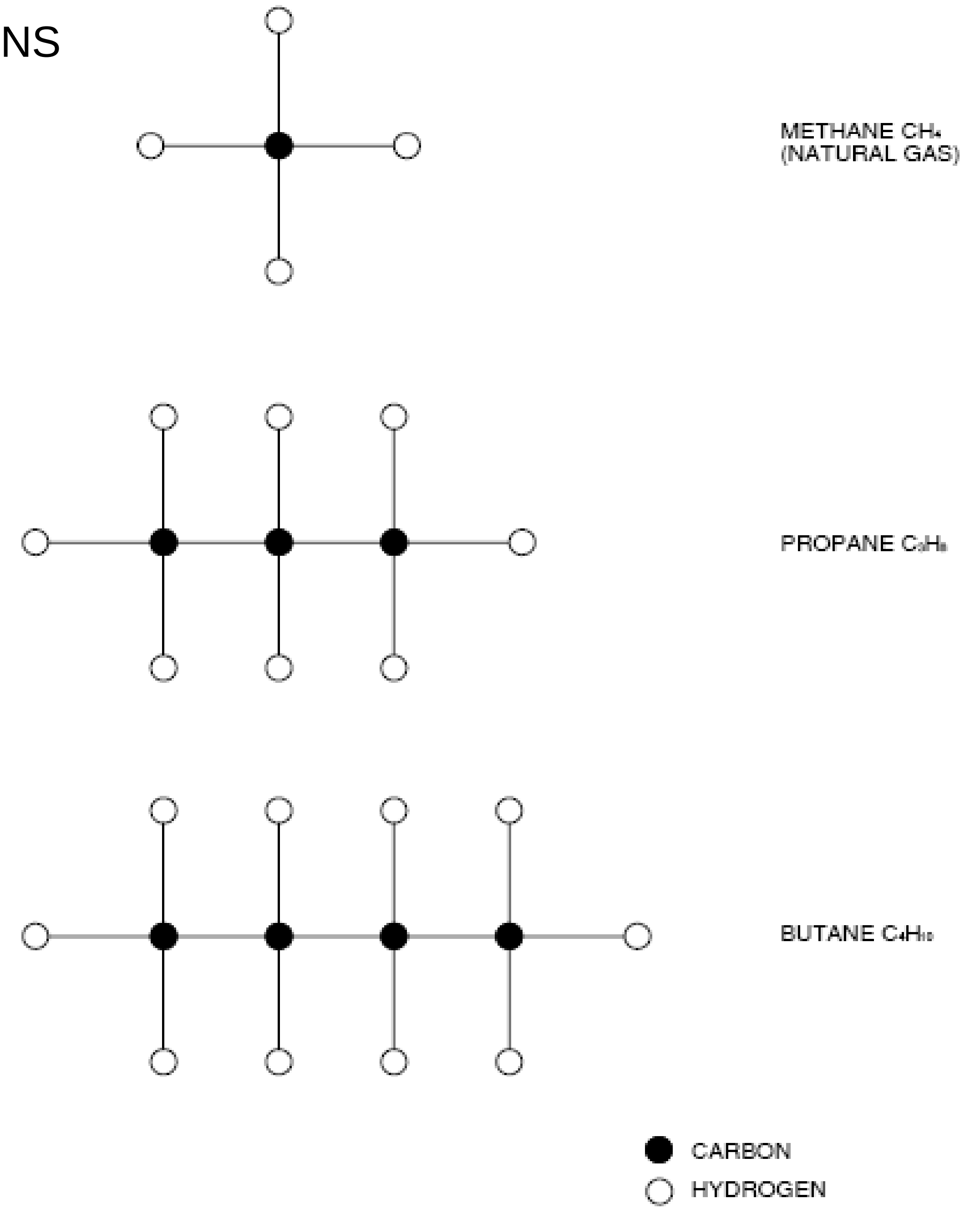
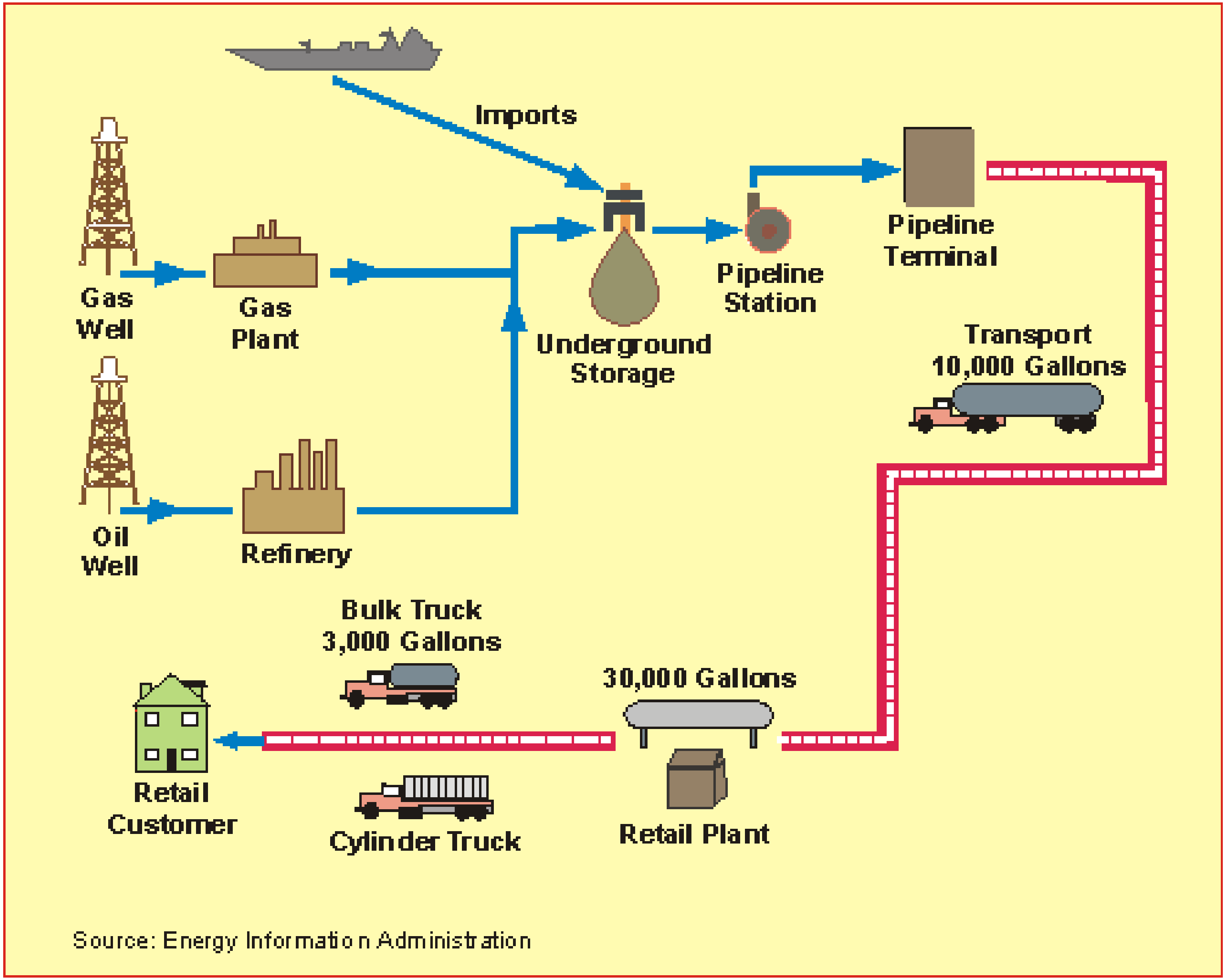
Part one

LPG
PHYSICAL & Chemical Properties

HYDROCARBONS



Processing & Refining LP-Gases



commercial Propane & Butane?
Ideally products referred to as "propane" and "butane" consist very largely of these saturated hydrocarbons; **but during the process of extraction/production certain allowable unsaturated hydrocarbons like ethylene, propylene, butylenes etc. may be included in the mixture along with pure propane and butane.** The presence of these in moderate amounts would not affect LPG in terms of combustion but may affect other properties slightly (such as corrosiveness or **gum formation**).

Kilojoules = 0.9478 BTU

Kcal = 3.968 BTU

Watt = 3.414 BTU

APPROXIMATE PROPERTIES OF LP-GASES

Table 1 (Metric)	PROPANE	BUTANE
Formula	C_3H_8	C_4H_{10}
Initial Boiling Point, °C	-42	-1
Specific Gravity of Liquid (Water = 1.0) at 15.56°C	0.504	0.582
Weight per Cubic Meter of Liquid at 15.56°C, kg	504	582
Specific Heat of Liquid, Kilojoule/Kilogram at 15.56°C	1.464	1.276
Cubic Meter of Vapor per Liter at 15.56°C	0.271	0.235
Cubic Meter of Vapor per Kilogram at 15.56°C	0.539	0.410
Specific Gravity of Vapor (Air = 1.0) at 15.56°C	1.50	2.01
Ignition Temperature in Air, °C	493-549	482-538
Maximum Flame Temperature in Air, °C	1,980	2,008
Cubic Meters of Air Required to Burn 1 Cubic Meter of Gas	23.86	31.02
Limits of Flammability in Air, % of Vapor in Air-Gas Mix:		
(a) Lower	2.15	1.55
(b) Upper	9.60	8.60
Latent Heat of Vaporization at Boiling Point:		
(a) Kilojoule per Kilogram	428	388
(b) Kilojoule per Liter	216	226
Total Heating Values After Vaporization:		
(a) Kilojoule per Cubic Meter	92,430	121,280
(b) Kilojoule per Kilogram	49,920	49,140
(c) Kilojoule per Liter	25,140	28,100
KW / Kg	**13.86**	**13.64**

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-Similar Properties

-Do not react with each other

-Propane is volatile and boils at -42deg C while Butane is less volatile and boils at 0.6 deg C.

- Both can be stored and transported at moderate pressure.

-Calorific value are almost equal.

-Both are mixed together to attain the vapor pressure that is required.

TEMPERA-TURE		TABLE 2 APPROXIMATE VAPOR PRESSURE, PSIG PROPANE → TO → BUTANE						
°F	°C	100%	80/20	60/40	50/50	40/60	20/80	100%
-40	-40	3.6	—	—	—	—	—	—
-30	-34.4	8	4.5	—	—	—	—	—
-20	-28.9	13.5	9.2	4.9	1.9	—	—	—
-10	-23.3	20	16	9	6	3.5	—	—
0	-17.8	28	22	15	11	7.3	—	—
10	-12.2	37	29	20	17	13	3.4	—
20	-6.7	47	36	28	23	18	7.4	—
30	-1.1	58	45	35	29	24	13	—
40	4.4	72	58	44	37	32	18	3
50	10	86	69	53	46	40	24	6.9
60	15.6	102	80	65	56	49	30	12
70	21.1	127	95	78	68	59	38	17
80	26.7	140	125	90	80	70	46	23
90	32.2	165	140	112	95	82	56	29
100	37.8	196	168	137	123	100	69	36
110	43.3	220	185	165	148	130	80	45

التوفير JD	تكلفة الستهلاك السنوي لنظام LPG tanks JD	تكلفة الاستهلاك السنوي لنظام لاسطوانات JD	الاستهلاك السنوي كغم	الاستهلاك الشهري كغم	الاستهلاك اليومي لتر	عدد الاسطوانات	الاستهلاك اليومي كغم
734.4	5385.6	6120	18000	1500	89.3	1	50
1468.8	10771.2	12240	36000	3000	178.6	2	100
2203.2	16156.8	18360	54000	4500	267.9	3	150
2937.6	21542.4	24480	72000	6000	357.2	4	200
3672	26928	30600	90000	7500	446.5	5	250
4406.4	32313.6	36720	108000	9000	535.8	6	300
5140.8	37699.2	42840	126000	10500	625.1	7	350
5875.2	43084.8	48960	144000	12000	714.4	8	400
7344	53856	61200	180000	15000	893	10	500

Odorization :

LP- Gases should be odorized prior to delivery to the bulk plant.

The warding added agent should be detected down to a concentration in air of one-fifth the lower flammability limit LFL or LEL

The most common is : Ethyl Mercaptan.

Combustion:

Complete Combustion

- Water Vapor
- Carbon Dioxide

Incomplete Combustion

- Carbon Monoxide (CO)
- Excessive Water Vapor
- Aldehydes
- Soot

Concentration of CO in Air	Physical Effect
9 ppm (0.0009%)	The Maximum allowable concentration for a short term exposure.
35 ppm (0.0035%)	The Maximum allowable concentration for continuous exposure for in any 8-hour period
200 ppm (0.02%)	Slight headache, tiredness, dizziness, nausea after 2-3H
400 ppm (0.04%)	Frontal Headache within 1-2 Hrs, Life threatening after 3Hrs
800 ppm (0.08 %)	Dizziness, nausea, and convulsions within 45minuts, Unconsciousness within 2 hours, Death within 1 hour
1600 ppm (0.16%)	Headache, dizziness and nausea within 20 minutes, Death within 1Hr
3200ppm (0.32%)	Headache, dizziness and nausea within 5-10 minutes, Death within 30 minutes.
6400 ppm (0.64%)	Headache, dizziness and nausea within 1-2 minutes, Death within 10-15 minutes
12800 ppm (1.28%)	Death within 1-3 minutes

10000 ppm = 1% by volume

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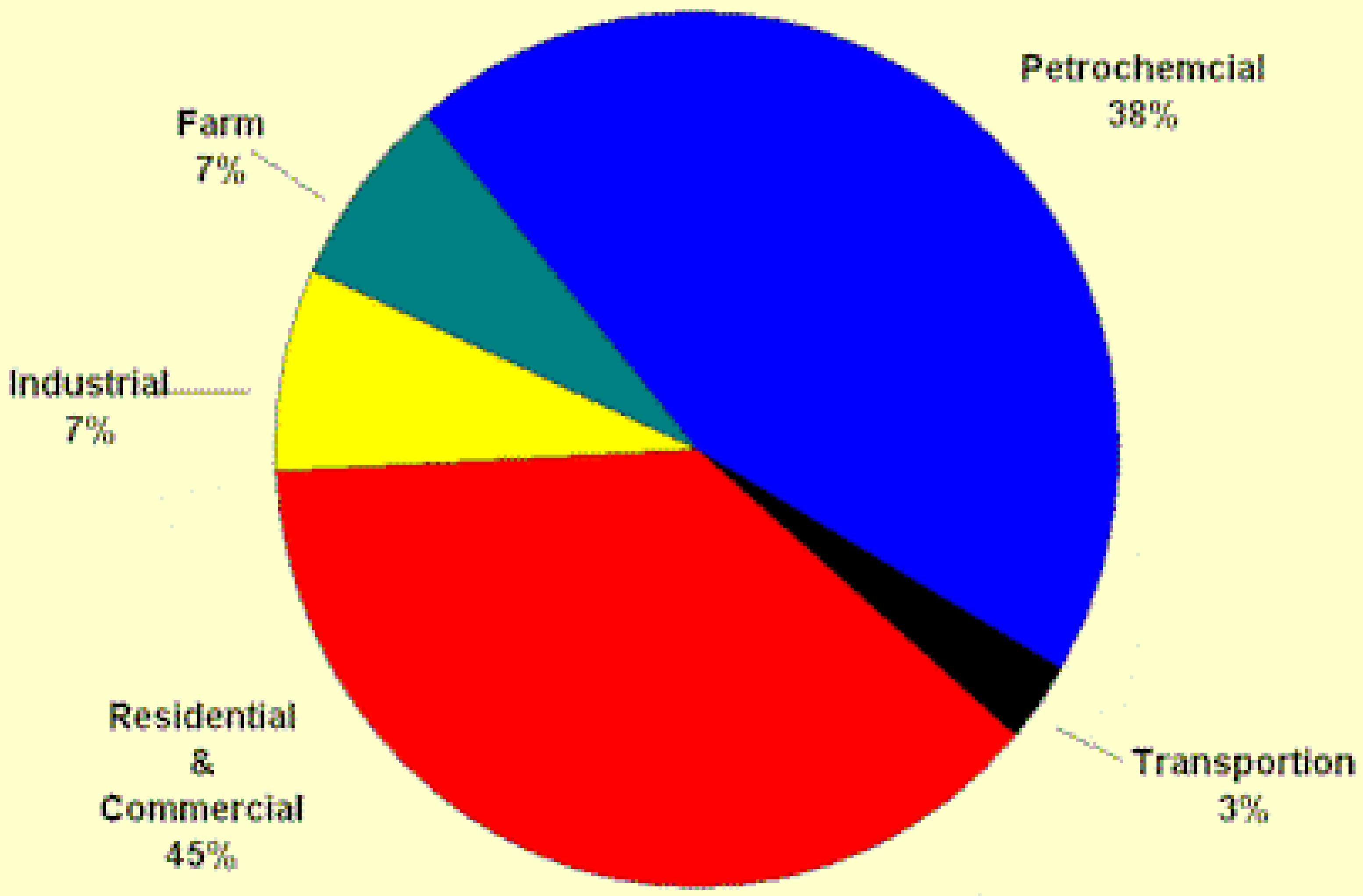
SOURCE	HEAT POWER	UNIT OF MEASUREMENT	USE OUTPUT	NET CALORIES PER UNIT OF MEASUREMENT	TOTAL CALORIES PER 1000 NET CALORIES	QUANTITY OF PRODUCT REQUIRED TO BE EQUAL TO 1KG OF PROPANE	UNIT OF MEASUREMENT
Propane	12.000	Cal/Kg	91	10.920	1.099	1	Kg
Natural Gas	9.000	Cal/mc	91	8.190	1.099	1,35	mc
Air-Prop.	12.000	Cal/mc	91	10.920	1.099	1	mc
Comb. Oil 3-5°E	10.300	Cal/Kg	75	7.725	1.333	1,45	Kg
Diesel	9.000	Cal/l	85	7.650	1.176	1,45	l
Kerosene	8.600	Cal/l	75	6.450	1.333	1,70	l
Wood	3.600	Cal/Kg	40	1.440	2.500	7,5	Kg
Dry wood	5.000	Cal/Kg	45	2.250	2.220	4,8	Kg
Carbon coke	7.000	Cal/Kg	50	3.500	2.000	3,1	Kg
Anthracite	8.000	Cal/Kg	50	4.000	2.000	2,7	Kg
Electricity	860	Cal/Kwh	100	860	1.000	12,7	kW



Source: American Petroleum Institute, *2000 Sales of*

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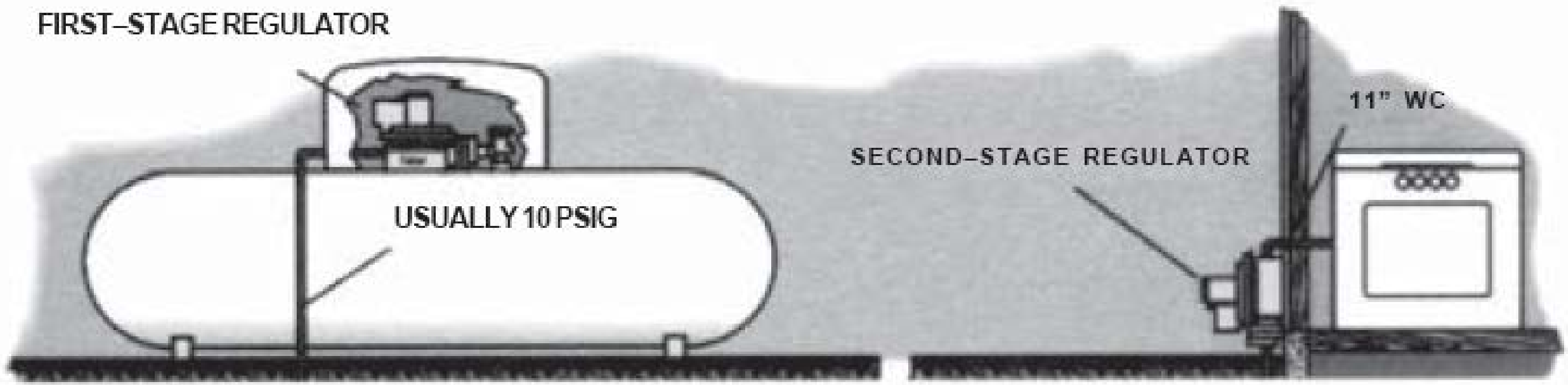
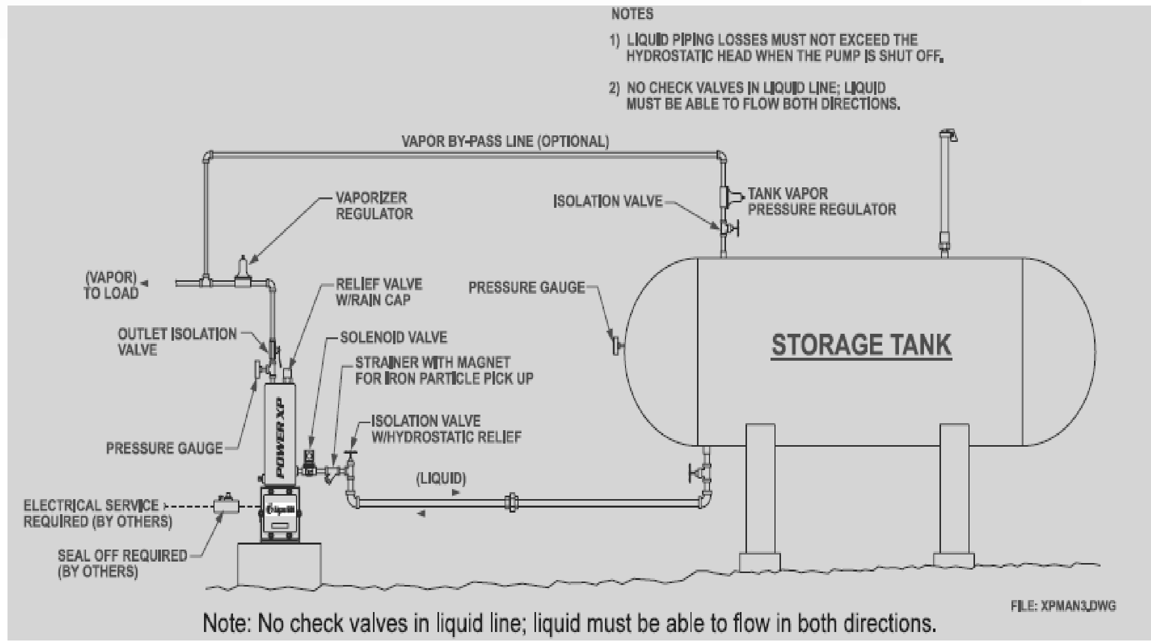
Part Two

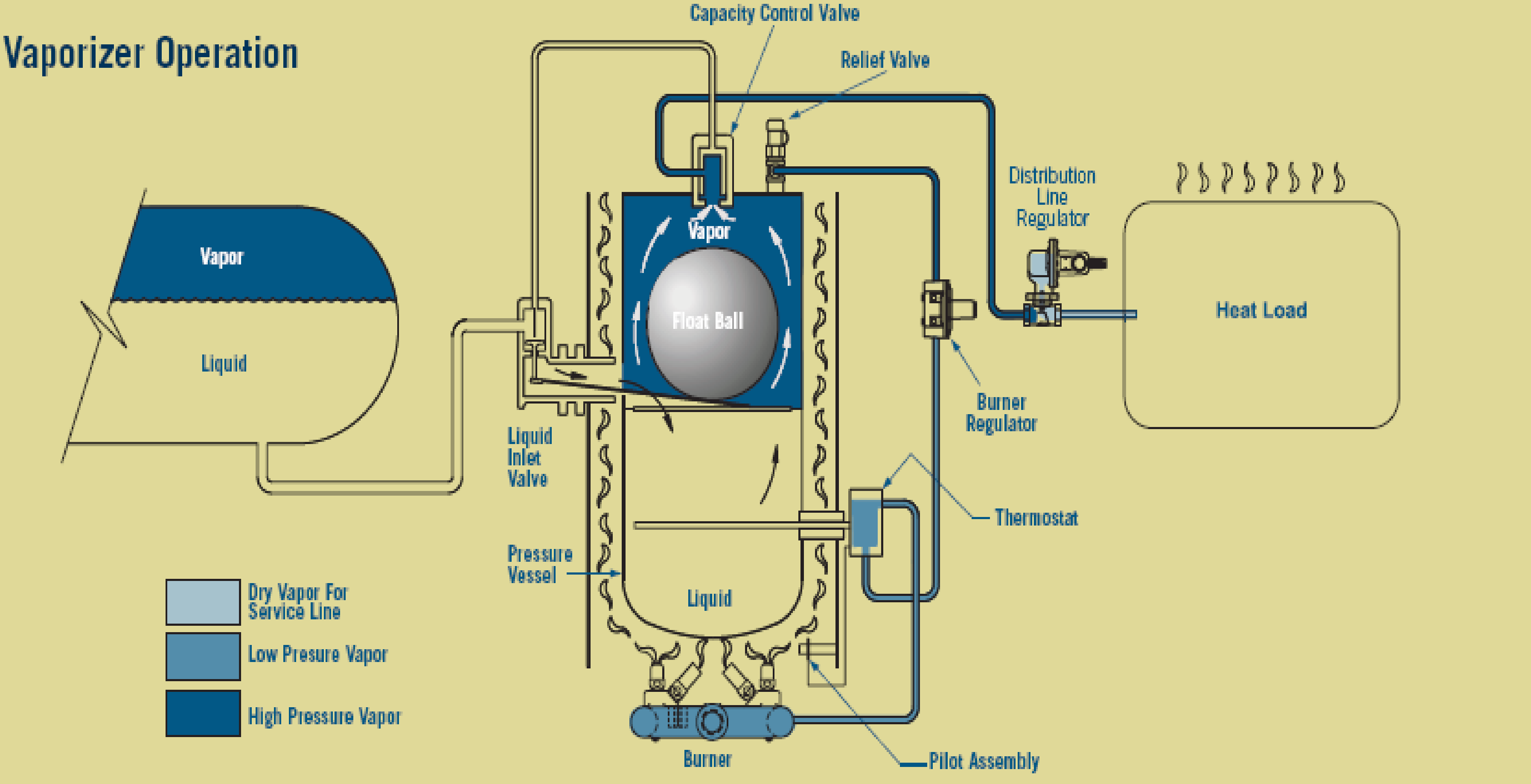
LPG System Components



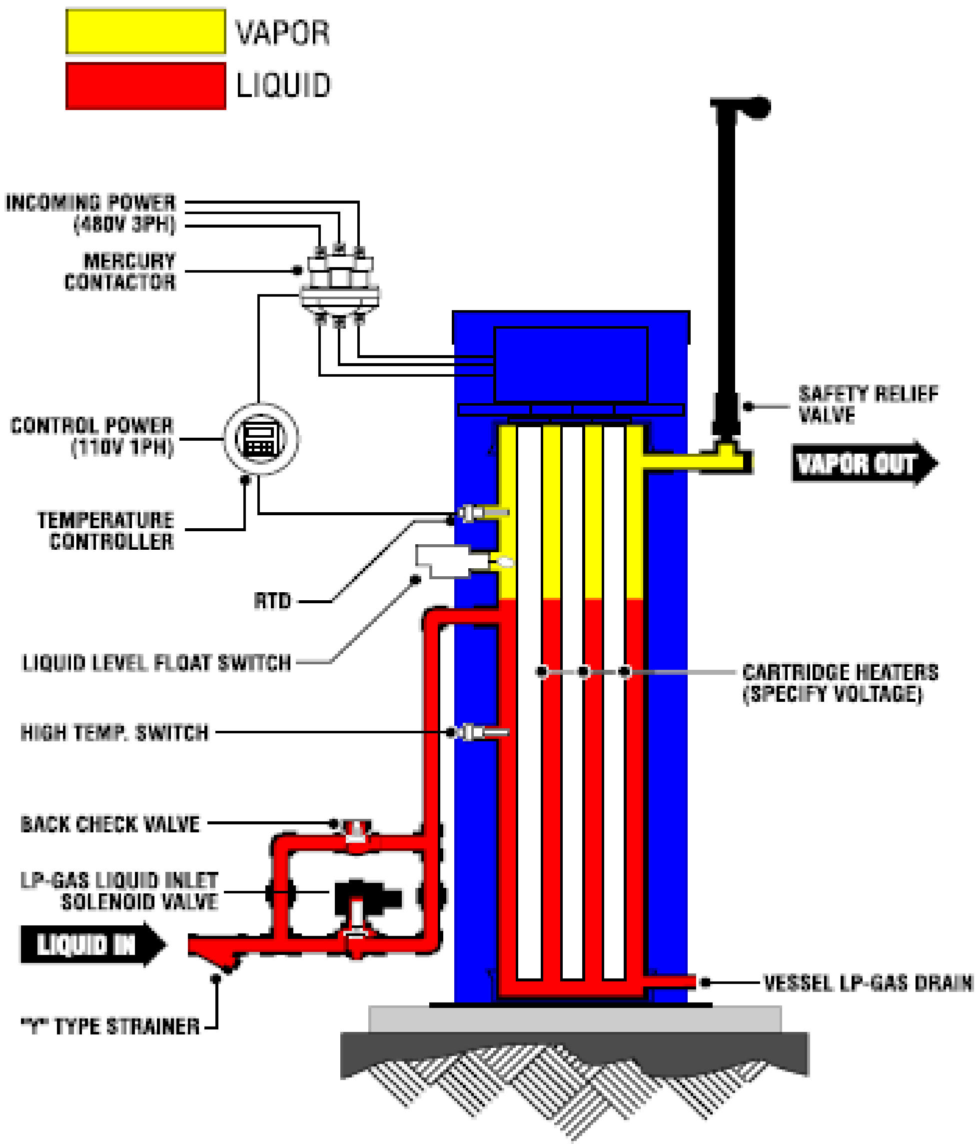
- LPG Tank / Cylinder
- Vaporizer
- 1st Stage Regulator
- LPG Feeding Pipe
- 2nd Stage Regulator
- Appliance
- Safety Equipment
    - Excess Flow Valves.
    - Relief Valves.
    - Anti- Seismic Valves.
    - Gas Leakage Detectors & Solenoid Valves.

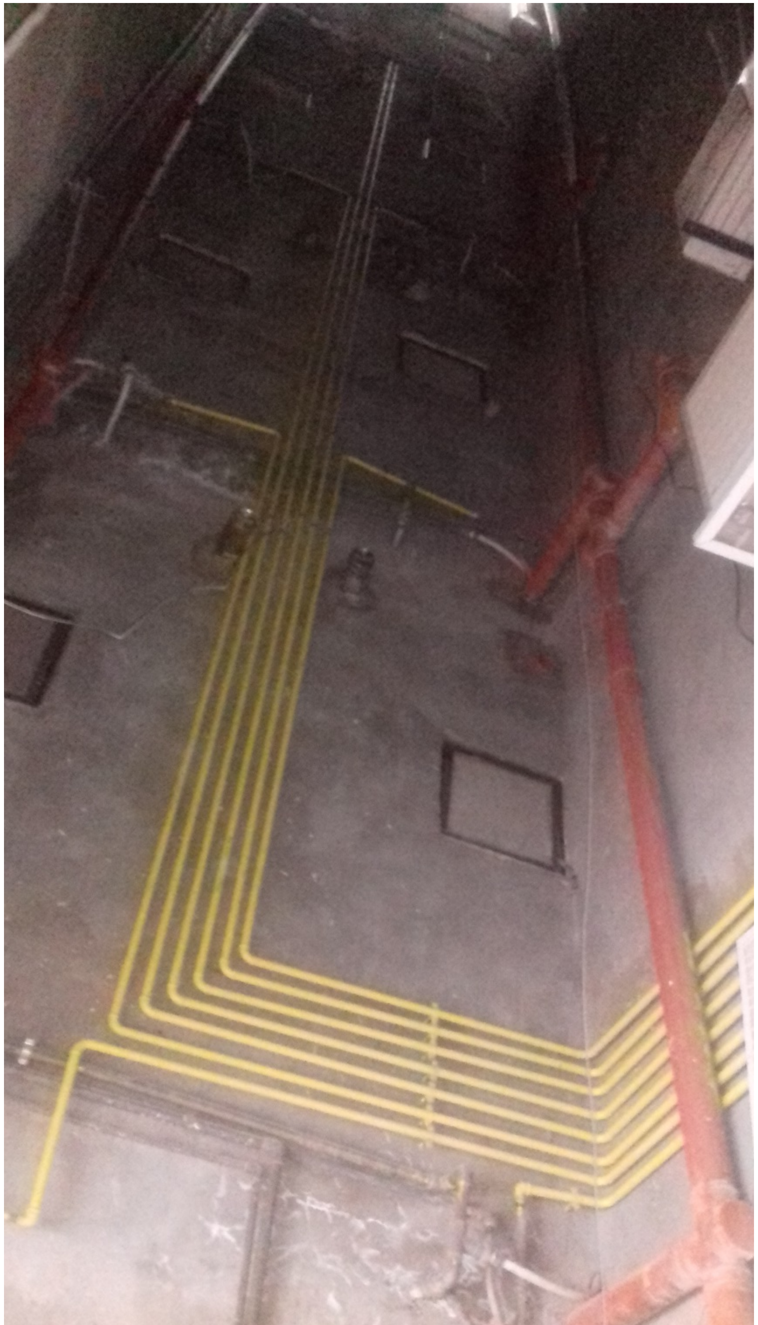


Vaporizer Operation



RE Series Electric Vaporizer






2011/2/17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LPG Tank - Codes of Design & Manufacturing , ASME versus EN

PED	ASME
European Directive 97/23/EC	Federal Law
Member State Law (e.g. UK, Germany, France etc.) Pressure Equipment Regulations.	State Law
□European harmonised Standards - Norms Give presumption of conformity for Essential Safety Requirements (ESR) of PED Annex I (e.g. EN 12952 - Water Tube Boilers EN 13445 - Unfired Pressure Vessels) Other Standards may be adopted provided that it is demonstrated that the PED ESRs are met.	Codes recognised by Law e.g. ASME Section I ASME Section VIII/1
Notified Bodies or Recognized Third Parties Certify Welding Procedures and Welders Notified Bodies Performs Design Examinations Performs Inspections for production under the inspection conformity assessment routes. Issues Certificates of Conformity	Manufacturers Approve Welders Code Inspection Agencies Perform Inspections Endorse Manufacturers Certification
Manufactures apply **CE** Marking and Notified Body unique identification (**Moody International = 1277**) number following issue of Notified Body certification of conformity. Manufacturer draws up a Declaration of Conformity	Manufacturer applies Code Stamp Manufacturers Draws up Certification

PART THREE

DESIGN ELEMENT OF LP-GAS SYSTEM

Main Design Elements are:

- Total Heat Load Required.
- Determination of Tank Size and quantity required.
- Vaporization capacity of the tanks/cylinders chosen.
- International and Local Standards and Codes obtained.

Determining Total Heat Load

Total Load = Σ appliances heat load in BTU

The best way to determine BTU input is from the appliance nameplate or from the manufacturer's catalog. Add the input of all the appliances for the total load.

Figuring the total load accurately is most important because of the size of the pipe and tubing, the tank (or the number of cylinders), and the regulator will be based on the capacity of the system to be served.

Table 3 Gas required for common Appliances

TABLE 3 GAS REQUIRED FOR COMMON APPLIANCES	
APPLIANCE	**APPROX. INPUT BTU/HR**
Warm Air Furnace	
Single Family	100,000
Multifamily, per unit	60,000
Hydronic Boiler, Space Heating	
Single Family	100,000
Multifamily, per unit	60,000
Hydronic Boiler, Space & Water Heating	
Single Family	120,000
Multifamily, per unit	75,000
Range, Free Standing, Domestic	65,000
Built-In Oven or Broiler Unit, Domestic	25,000
Built-In Top Unit, Domestic	40,000
Water Heater, Automatic Storage, 30 to 40 gal. Tank	35,000
Water Heater, Automatic Storage, 50 gal. Tank	50,000
Water Heater, Automatic Instantaneous	
Capacity 2 gal. per minute	142,800
Capacity 4 gal. per minute	285,000
Capacity 6 gal. per minute	428,000
Water Heater, Domestic, Circulating or Side-Arm	35,000
Refrigerator	3,000
Clothes Dryer, Type 1 (Domestic)	35,000
Gas Fireplace direct vent	40,000
Gas log	80,000
Barbecue	40,000
Gas Light	2,500
Incinerator, Domestic	35,000

Table Reprinted From Table 5.4.2.1, NFPA 54, 2002 ed.

Vaporization Rate

$$Q=kA(Ta-Ts)/Cv$$

Q [m3)h] ; k [kcal/h ºC m2] ; Ta =ambient Temperature
Ts= Temperature correspondent to the vaporization pressure inside the vessel
Cv= Latent heat for the liquid to the temperature inside the vessel
A= Wet Area

Dependent upon the **temperature** of the liquid and the amount of "**wetted surface" area** of the container.

Effects

Withdrawal of gas from one or two containers can lower the container pressure substantially due to the refrigeration of the vaporization gas
Regulator capacity is then reduced because of the lower inlet pressure.

Solutions

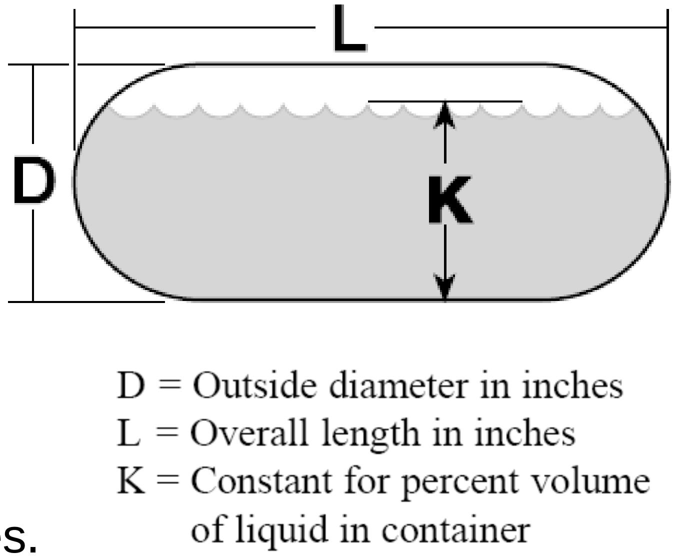
Multiple cylinders or tanks may be manifolded to give the required vaporization capacity..

Vaporizers is to be used

Ruff Estimation of vaporization capacities :

A number of assumptions were made

1) The tank is one-half full.
2) Relative humidity is 70%.
3) The tank is under intermittent loading.



the Table can still serve as a good rule-of-thumb in estimating what a particular tank size will provide under various temperatures.

UNDER Continuous loading the withdrawal rates in the Table should be multiplied by 0.25

* Tank frosting acts as an insulator, reducing the vaporization rate.

Vaporization Rates for 100 Pound DOT Cylinders

For continuous draws, where temperatures may reach 0°F, -17 ˚C , assume the vaporization rate of a 100 lb. cylinder to be approximately 50,000 BTU/HR Therefore : Number of cylinders per side = total load in BTU/HR / 50,000

Example:

If a total load requirement of 200,000 BTU/HR is to be supplied from 100 pound DOT cylinders and winter temperatures may drop to 0°F, then how many cylinders are needed per side?

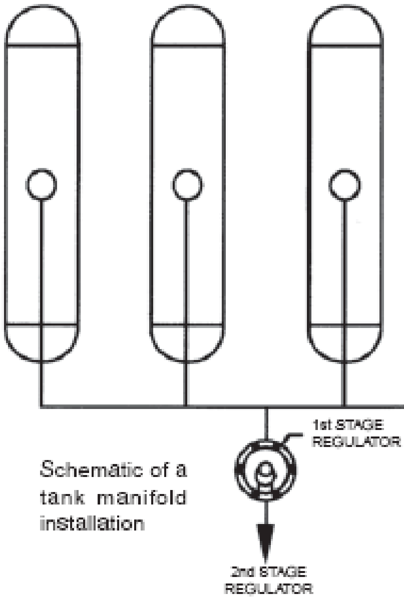
Number of cylinders per side = 200,000/50,000 = 4

Vaporization Rate Table for 100 Lb. DOT Cylinders

TABLE 5 VAPORIZATION RATES IN BTUH FOR VARIOUS TEMPERATURES AND LIQUID LEVELS				
LBS. OF PROPANE IN CYL.	-20°F	0°F	20°F	40°F
100	65,000	71,000	79,000	94,000
90	60,000	65,000	72,000	85,000
80	54,000	59,000	66,000	77,000
70	48,000	52,000	59,000	69,000
60	43,000	46,000	52,000	61,000
50	37,000	40,000	45,000	53,000
40	31,000	34,000	38,000	45,000
30	26,000	28,000	31,000	37,000
20	20,000	22,000	25,000	29,000
10	15,000	16,000	18,000	21,000

Table 4 Max. Intermittent Withdrawal Rate (BTU/HR) Without Tank Frosting* if Lowest Outdoor Temperature (Average For 24 Hours) Reaches . . .				
TEMPERATURE	TANK SIZE (GALLONS)			
	150	250	500	1,000
40°F	214,900	288,100	478,800	852,800
30°F	187,900	251,800	418,600	745,600
20°F	161,800	216,800	360,400	641,900
10°F	148,000	198,400	329,700	587,200
0°F	134,700	180,600	300,100	534,500
-10°F	132,400	177,400	294,800	525,400
-20°F	108,800	145,800	242,300	431,600
-30°F	107,100	143,500	238,600	425,000

* Tank frosting acts as an insulator, reducing the vaporization rate.



Schematic of a tank manifold installation

TEMPERATURE		TABLE 2 APPROXIMATE VAPOR PRESSURE, PSIG PROPANE → TO → BUTANE						
°F	°C	100%	80/20	60/40	50/50	40/60	20/80	100%
-40	-40	3.6	—	—	—	—	—	—
-30	-34.4	8	4.5	—	—	—	—	—
-20	-28.9	13.5	9.2	4.9	1.9	—	—	—
-10	-23.3	20	16	9	6	3.5	—	—
0	-17.8	28	22	15	11	7.3	—	—
10	-12.2	37	29	20	17	13	3.4	—
20	-6.7	47	36	28	23	18	7.4	—
30	-1.1	58	45	35	29	24	13	—
40	4.4	72	58	44	37	32	18	3
50	10	86	69	53	46	40	24	6.9
60	15.6	102	80	65	56	49	30	12
70	21.1	127	95	78	68	59	38	17
80	26.7	140	125	90	80	70	46	23
90	32.2	165	140	112	95	82	56	29
100	37.8	196	168	137	123	100	69	36
110	43.3	220	185	165	148	130	80	45

1 - Standards & Codes
NFPA codes & standards used in the LPG Industry

Title	Document No	Application
Cutting , welding & allied processes and cutting & welding process	51 51B	Standards covering the use of fuel gases and fuel / oxygen systems in cutting , brazing and welding
National Fuel Gas Code	# 54	Standards covering Installation of gas piping and appliance in residential and commercial areas
LP-Gas Code	# 58	Standards covering the storage, handling and transportation of LPG
Liquefied Petroleum Gases at utility gas plants	# 59	Standards covering construction and operation of LPG equipment at plants owned by Natural gas utilities.
National Electric Code	# 70	Standards covering the installation of electrical wiring, motors ,electrical controls including hazardous & classified areas
Pleasure & Commercial motor craft	# 302	Standards covering fire protection for boats including LPG systems within
Manufactured Housing	# 501 # 501 A	Standards covering manufactured homes
Recreational Vehicles Recreational Vehicle Parks	# 1192 # 1194	Standards covering installation of gas piping in RV's & Rv's campgrounds
Industrial trucks	# 505	Standards covering type designation, areas of use, maintenance and operation of LPG powered industrial trucks

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2- Choosing the Proper Size and Quantity of Tanks

Controlling Elements :

a) Total Load
b) Vaporization Rate required.
c) Location of facility and refilling time interval required.
d). Physical Place Available.

Container Locations & preparations
1- General Conditions / NFPA 58

Located outside of buildings	6.2.1
Separation Distances between containers, Important buildings and other properties / Table 6.3.1* Distance is measured from the relieve valve / filling connection	6.3.1
Distance from point of discharge of the relief valve of a container or vents or container filling connection, to any openings, or source of ignition to be as table 6.3.9	6.3.9 6.3.10
The horizontal distance between any portion of the building that overhangs out of the building wall (balcony) and the underneath Gas Tank bigger than 473Liter shall be 50% of the distances given in table 6.3.1 conditioned that it is less than 15m above the tank and extend more than 1.5m from the building	6.3.12
No loose or piled combustible material and weeds and long dry grass within 3m distance.	6.4.5.2
LPG containers to have minimum 3m separation distance from wall of diked areas containing flammable or combustible liquids	6.4.5.4

Separation between LPG tanks and tanks containing flammable or combustible liquids if either is above ground while the other is underground.	6.4.5.6
No structures around the LPG tanks other than a fence for security against tampering	6.4.7
Point of transfer of containers located in stationary installations if it is NOT located at the container, it shall be located in accordance with table 6.5.3	6.5.3
Protection from damage from vehicles.	6.6.1.2
All operating appurtenances of the container are accessible	6.6.1.5
Where high flood waters that may result of tank floatation is possible , tanks to be securely anchored.	6.6.1.6

Container Locations & preparations

2- Above Ground Tanks

Single installation of Above Ground Containers > 0.5m³ but less than 4.5 m³ have a reduced distance of 3 meter from an important building	6.2.1
For Buildings devoted to gas distribution/ manufacturing and made of other than wood-frame, distance shall be reduced to 3 meters regardless size of tank.	6.3.1
For multi-container installation less than 500 Liters that are manifolded together ; exceeding 1900 Liters hall be considered with the aggregated water capacity for the distances from important building . No separation among the aggregated tanks is required.	6.3.9 6.3.10
Above ground multi-container installation composed of several 45m³ or more shall have limited No. of tanks per group with separation distances between groups a per table 6.4.2 unless provisions 6.24.3 and 6.24.4 are met then distance is reduced to 50% of that mentioned in table 6.4.2	6.3.12
Minimum horizontal distance separate above ground LPG tanks from above ground flammable tank storage material with flash point of les than 93.4ºC other than LPG hall be 6m.	6.4.5.2
Any Part of Above Ground LPG tank shall not be located within 1.8m of a vertical plane beneath overhead electrical power line **over 600 V**.	6.4.5.4

Horizontal Containers Structural Support	6.6.3.1
Interconnected Tanks to have same level of elevation	6.6.3.2
Horizontal permanent containers attached with the same support must comply to table 6.6.3.3.	6.6.3.3
The part of he container in contact with the foundation shall be coated or protected to minimize corrosion.	6.6.3.5
Where snow accumulation anticipated is more than the height of the container, excluding the dome, then a take or other marking to be present and container to be fixed preventing it movement resulting from snow accumulation.	6.6.3.6

Container Locations & preparations
3- Underground

Containers of **7.6m3** to **114 m3** water capacity satisfies all provisions of section 6.24 shall have a reduced distance of 3 meters only from important buildings.	6.3.4
No part of the underground tank is less than 3 meters from a building or line of adjoining property that can be built upon (another future building if to be existed within the adjoining property)	6.3.4.2
For Mounded containers, No part that I installed above grade shall be less than 1.5 meter from a building.	6.3.4.3
Containers to be located outside of any building	6.4.4.1
Buildings shall not be constructed over any underground or mounded container.	6.4.4.2
The sides of adjacent containers shall be separated in accordance with Table 6.3.1 but not les than 1 meter	6.4.4.3
No limited number of containers for one group if it is installed parallel with ends in line.	6.4.4.4

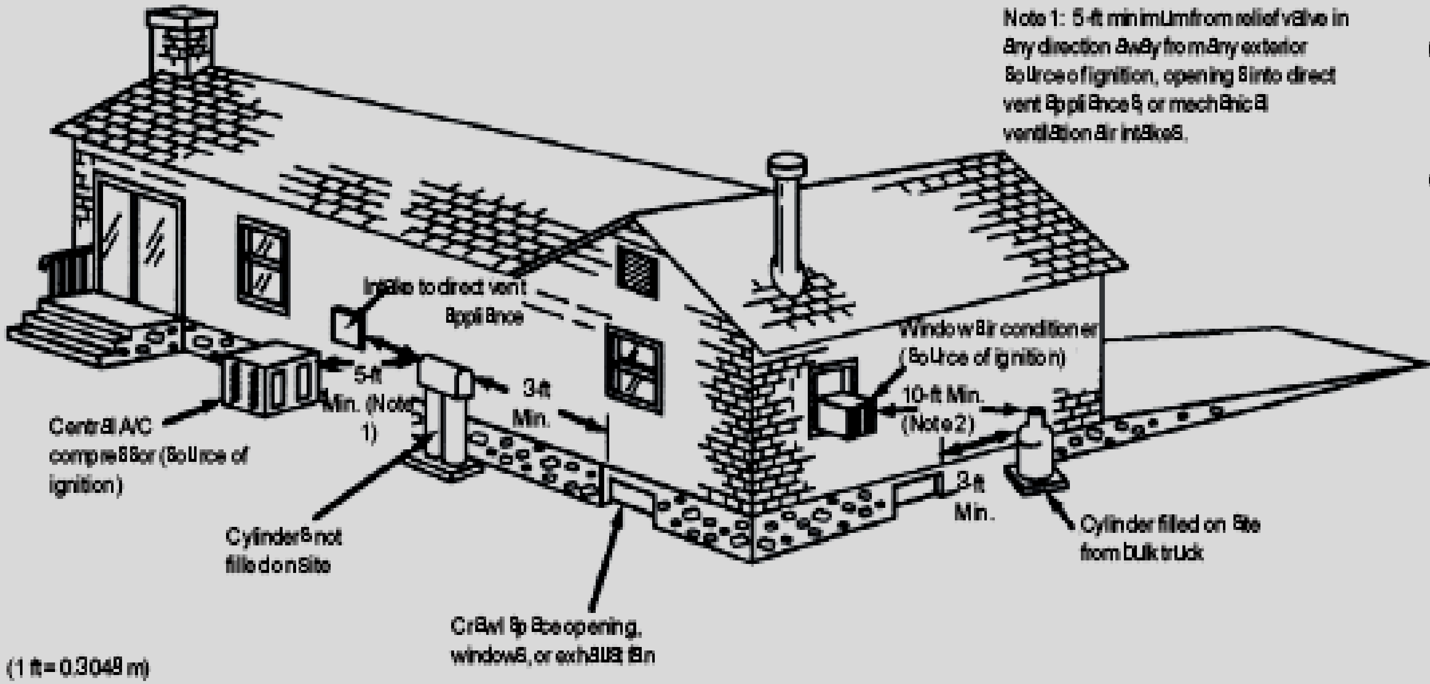
Where more than one raw of containers is installed the adjacent ends of the containers in each row shall be separated by not less than 3 meters.	6.4.4.5
Installation of underground containers in accordance with the following; - In areas with no vehicle traffic; minimum 15 cm below grade. - In areas where traffic is expected; either a minimum of 46cm below grade or protection from damage from vehicles. - Protection shall include fitting and tank connections against vehicular damage. - Protection to be done if traffic is expected within 3 meters from the container. - Vents and relief pipes to be above highest probable water level. - Container is set leveled and surrounded by earth or sand firmly tamped in place.	6.6.6.2
Mounded containers to be mounded by earth or sand or other non combustible material and covered of at least 30 cm .	6.6.6.3.(1)

Container valves and appurtenances to be accessible. If mounded container bottom is 76cm or more above the surrounding grade; access to bottom connections if any to be provided and this connection to be considered as part of the container with all code applies on it.	6.4.4.5

**Distance for all underground and mounded containers shall be measured from the pressure relief valve and filling connection. (Article 6.3.4.1 // Page 58-27).

CONTAINER LOCATION (cont)

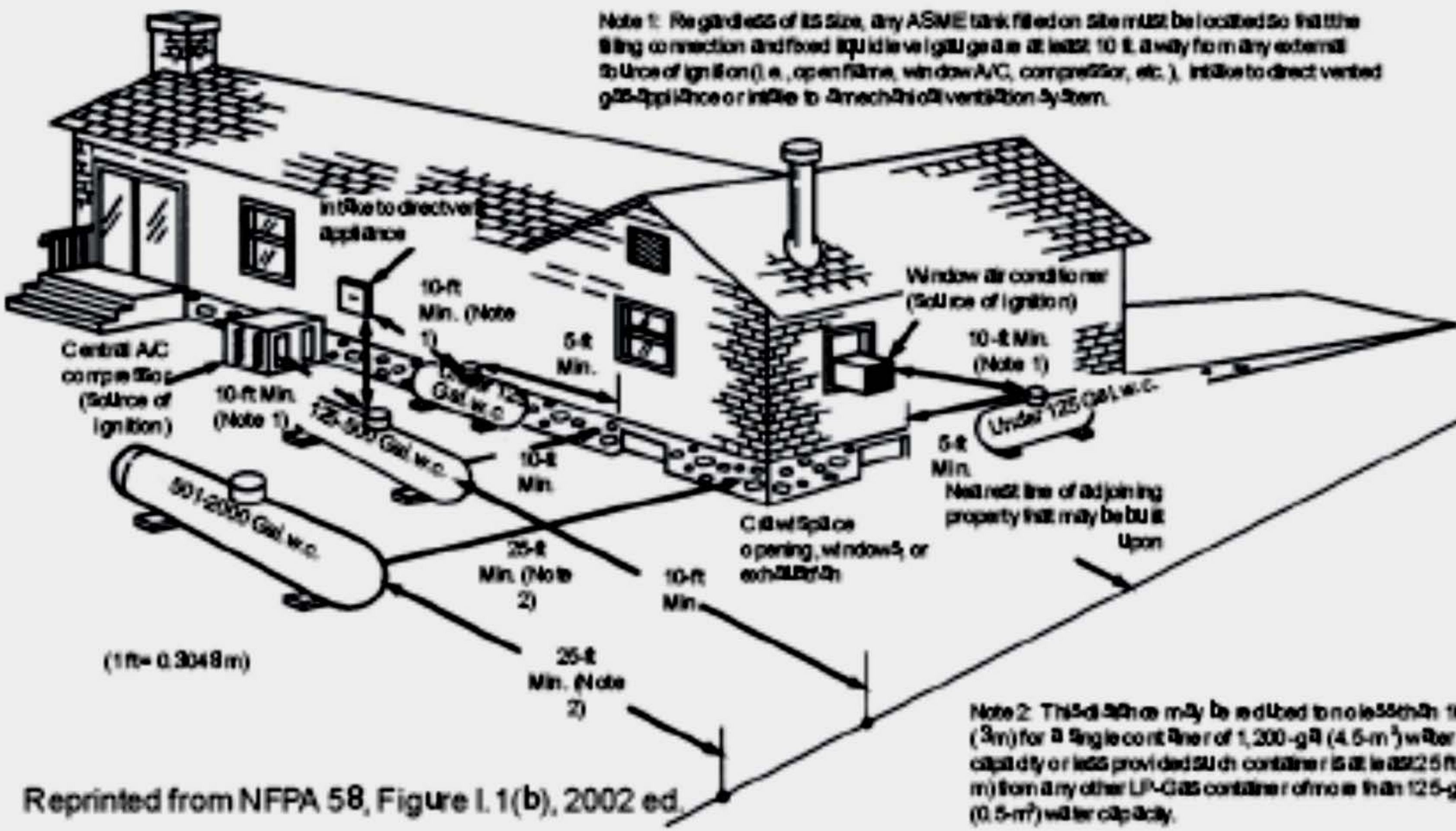
Figure 3 Cylinders



Note 1: 5-ft minimum from relief valve in any direction away from any exterior source of ignition, openings into direct vent appliances, or mechanical ventilation air intakes.

Note 2: If the cylinder is filled on site from a bulk truck, the filling connection and vent valve must be at least 10-ft from any exterior source of ignition, openings into direct-vent appliances, or mechanical ventilation air intakes.

Reprinted from NFPA 58 Figure I.1(a), 2002 ed.

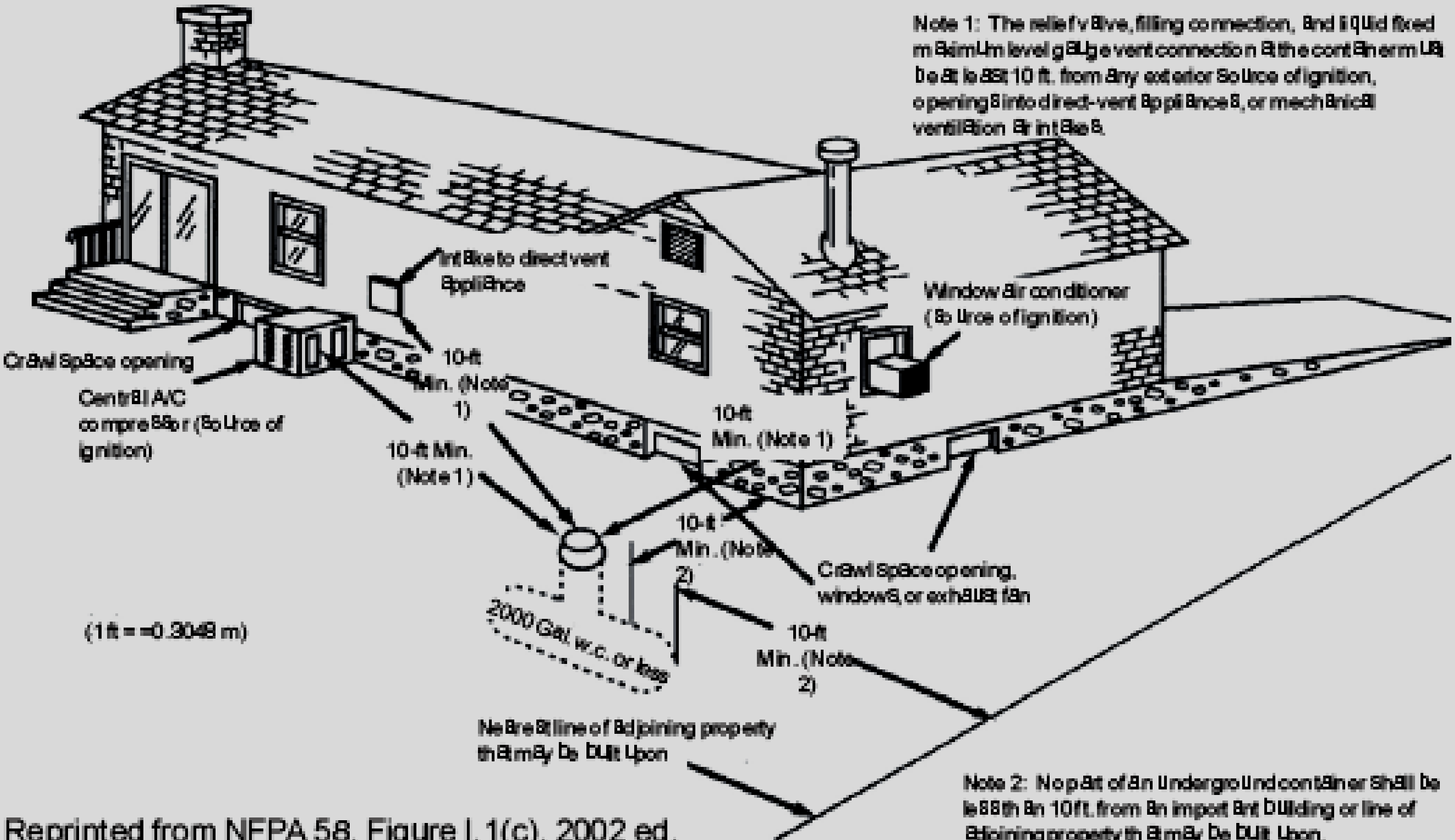


Reprinted from NFPA 58, Figure I.1(b), 2002 ed.

Figure 4 Above Ground ASME Containers

CONTAINER LOCATION (cont)

Figure 5 Below Ground ASME Containers



Reprinted from NFPA 58, Figure I.1(c), 2002 ed.

Tank Preparation

REMOVING WATER FROM CONTAINERS

Water in LP-Gas cylinders and tanks can contaminate the gas, causing regulator freezeups and erratic appliance performance.

Adding anhydrous methanol (99.85% pure) will neutralize any moisture within the container.

This will minimize freeze-up problems for normal amounts of water in a container.

Table 6

CONTAINER SIZE	MINIMUM AMOUNT OF METHANOL REQUIRED
100 lb. cylinder	1/8 Pint (2 fluid ounces)
150 gal. tank	1 pint
250 gal. tank	1 quart
500 gal. tank	2 quarts
1000 gal. tank	1 gallon

Warning: Do not substitute other alcohols in place of methanol.

PURGING AIR FROM CONTAINERS

Air in the LP-Gas can cause appliance pilot lights to be extinguished easily.
It can also lead to excessive container pressure, making the safety relief valve open.

1) Bleed the air to atmosphere by opening the multi-purpose valve or the service valve for several minutes until air pressure is exhausted. Close the valve.

2) Attach the truck vapor equalizing hose to the multipurpose valve’s vapor equalizing valve or the separate vapor-equalizing valve.

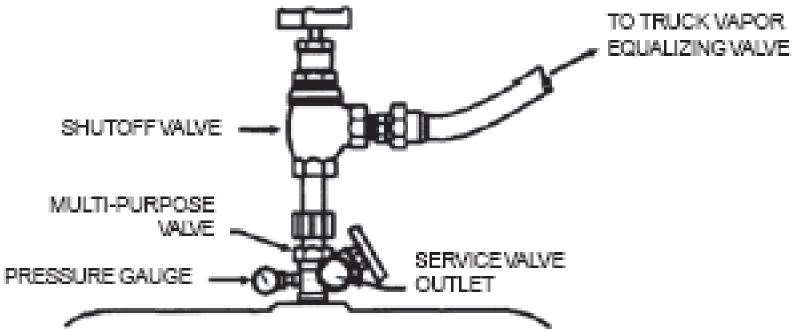
4) Slowly open the shutoff valve on the end of the hose so that the truck excess flow check valve does not slam shut.

5) Closely watch the pressure, and when the gauge reaches 15 psig, close the shutoff valve.

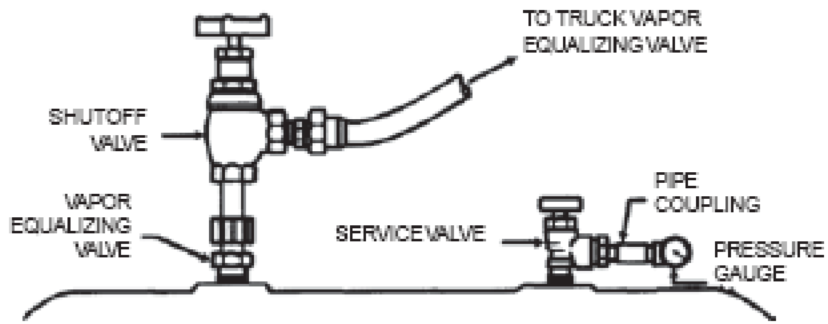
6) Open the vapor service valve on the multi-purpose valve or the separate service valve, Allow all pressure to be exhausted before closing the multi-purpose valve or the service valve.

7) Repeat steps 4 through 6 at least **three** more times to make certain air has been purged from the tank.

PURGING METHOD WITH MULTI-PURPOSE VALVE



PURGING METHOD WITH SEPARATE VALVES



Note: Do not purge tanks in this way on the customer's property. Purge them in a safe place at the bulk plant site.

Pipe Selection

- Essential for efficient operation.
- Deigned for Maximum gas demand + Future expansion.

Factors affects the selection of type of pipe to be used:

- Location ; indoor or out door.
- State of Gas : Liquid or Vapor.
- Pressure .
- Risk of mechanical damages.

Type of Pipe :-

- Wrought iron/ Steel Pipe; Installed as per ASME B31.3, welded as per ASME V111,

- Copper ; Seamless tube/ pipe, Type K or L

- PE; high density pipe. (out door + under ground + Pressure< 30 psig)

Four different areas of sizing requirements must be addressed:

1) Sizing between First-Stage and Second-Stage Regulators

2) Sizing between Second-Stage Regulator and Appliance

3) Sizing between 2 PSI Service and Line Pressure Regulators

4) Sizing between Line Pressure Regulator and Appliance

Type of Metallic Joints in LP-Gas

Service	**Schedule 40**	**Schedule 80**
Liquid	Welded	Threaded or Welded
Vapor ≤125 psig	Threaded or Welded	Threaded or Welded
Vapor > 125 psig	Welded	Threaded or Welded

Directions for Sizing between First-Stage and Second-Stage Regulators (Based on NFPA 54 Hybrid Pressure Method)

1) Measure the required length of pipe or tubing from the outlet of the first-stage regulator to the inlet of the second-stage regulator.

2) Determine the maximum gas demand requirements of the system by adding the BTU/HR inputs from the nameplates of all the appliances or by referring to Table 3 on page 5.

3) Select the pipe or tubing required from Tables 7a, b,and c on pages 23-25.

Directions for Sizing Between Second-Stage Regulator and Appliance
(Based on NFPA 54 Longest Length Method)

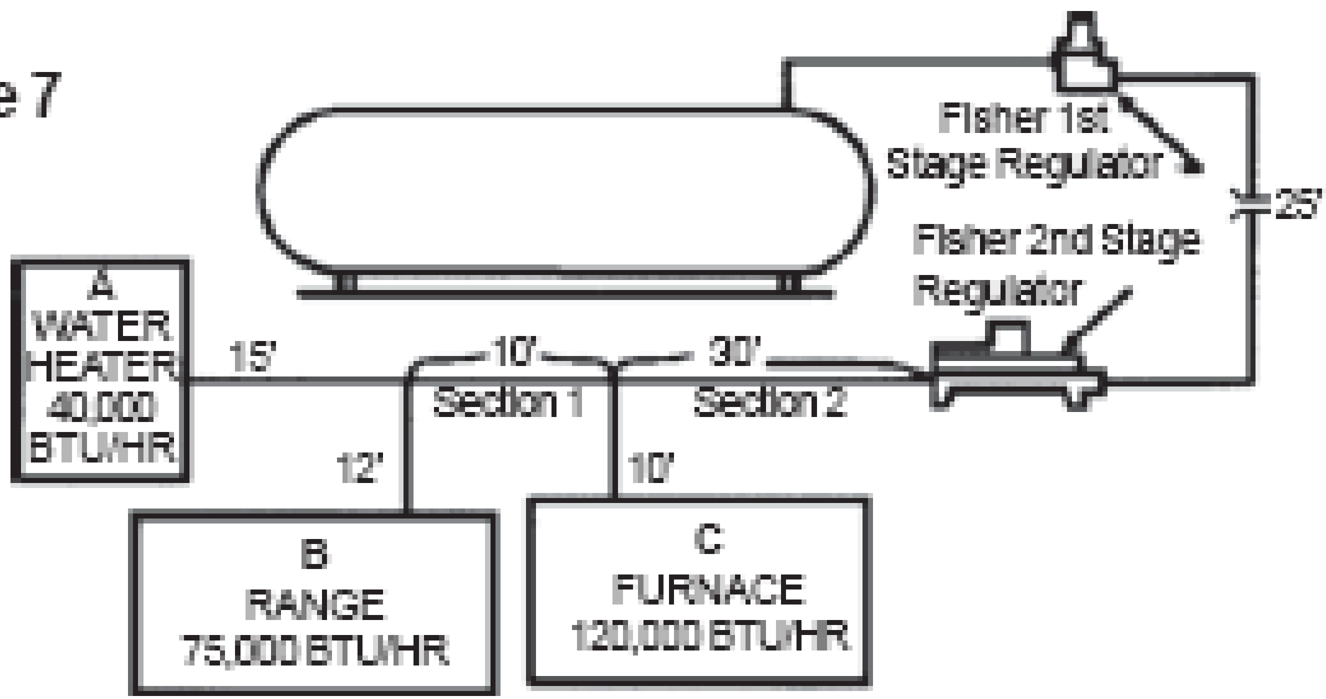
1) Measure the length of pipe or tubing from the outlet of the second-stage regulator to the most remote appliance.
   (Note: This is the only length needed to size the second-stage system.)
2) For each outlet and section of pipe, determine the specific gas demand requirements by adding the BTU/ HR inputs from the nameplates of each appliance or by referring to Table 3 on page 5.
3) Select the pipe or tubing required for each section from Table 8a or 8b on pages 26 and 27.

Determine the sizes of pipe or tubing required for this two-stage LP-Gas installation.

Example:

A private home is to be supplied with a LP-Gas system serving a central furnace, range and water heater. The gas demand and piping lengths are shown on the sketch below.

Figure 7



For First-Stage:

1) Length of first-stage piping = 25 feet (round up to 30 ft. for use in Table 7a, b, c.).

2) Total gas demand = 40,000 + 75,000 + 120,000 = 235,000 BTU/HR.

3) From Tables 7a, b, and c, use 1/2” iron pipe; or 1/4” Type L or ¾” CR copper tubing or 1/2” plastic tubing. (Assume a 10 psig first-stage regulator setting and a 1 psig pressure drop.)

For Second-Stage:

1) Total second-stage piping length = 30 + 10 + 15 = 55 feet (round up to 60 ft. for use in Table 8a and 8b).
2) Gas demand requirements and pipe selection from Table 8a and 8b (Assume a 11” w.c. setting and 1/2” w.c. pressure drop):

For Outlet A, demand = 40,000 BUT/HR, use 1/2” iron pipe or 3/8” Type L or 5/8" ACR copper tubing.

For Outlet B, demand = 75,000 BUT/HR, use 1/2” iron pipe or 1/2” Type L or 5/8” ACR copper tubing.

For Outlet C, demand = 120,000 BUT/HR, use 3/4” iron pipe or 5/8” Type L or 3/4” ACR copper tubing.

For Section 1, demand = 40,000 + 75,000 = 115,000 BTU/HR, use 3/4” iron pipe or 5/8” Type L or 3/4” ACR copper tubing.

For Section 2, demand = 40,000 + 75,000 + 120,000 = 235,000 BTU/HR, use 1” iron pipe.

Pipe Selection Tables

RESISTANCE OF VALVES & FITTINGS IN EQUIVALENT FEET OF PIPE

	PIPE SIZE						
	1	1 ¼	1 ½	2	2 ½	3	4
Elbow 90	4	4 ½	5	6	8	9	11
Elbow 45	1	2	2	2 ½	3	4	5
Tee thru side	6	8	9	12	14	17	22
Y strainer same size as pipe	25	25	25	42	42	42	60
Y strainer next larger size	16	16	16	16	14	20	
Globe valve	28	35	45	60	65	85	120
Angle valve	15	19	22	28	35	42	57
Ball valve	½	½	½	½	½	½	½
Quick-closing gate	3	3	3	3	3	3	3

Above values are approximate and will vary from one manufacturer to another

SELECTING THE REGULATOR

Effective elements:

1 - Total Load Requirement.

2 - Inlet Pressure

3 - Outlet Pressure

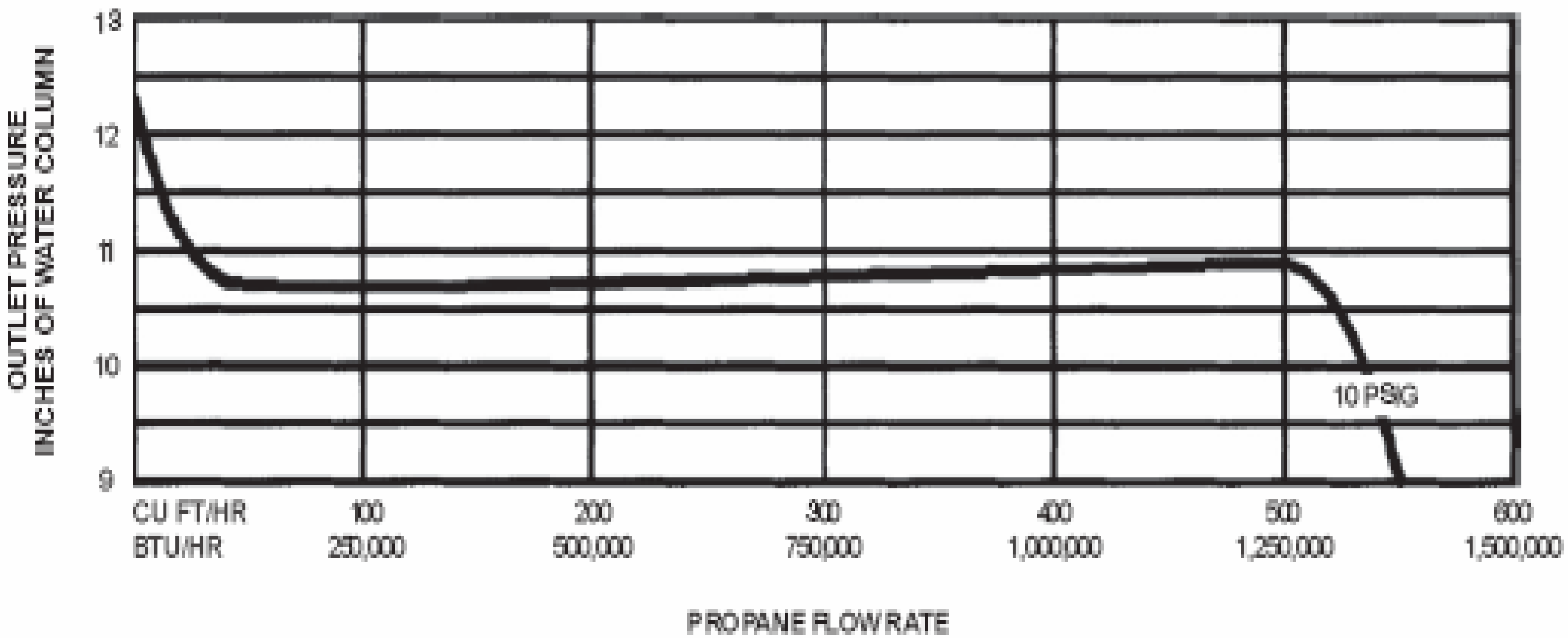
4 - Regulator performance curves

5 - Type of Gas used

6- Pipe Size

TYPICAL CAPACITY CURVE

Figure 9



The figure above shows a performance curve which demonstrating the capacity of a regulator at different inlet pressures, given the factory setting for outlet pressure.

TWO-STAGE REGULATION

Advantages of Two-Stage Regulation

Uniform Appliance Pressure - Two-staging lets the first stage regulator supply a nearly constant inlet pressure tothe second-stage regulator at the house. This means the second-stage regulator has an easier time of maintaining appliance pressure at 11” w.c., thus improving the system efficiency.

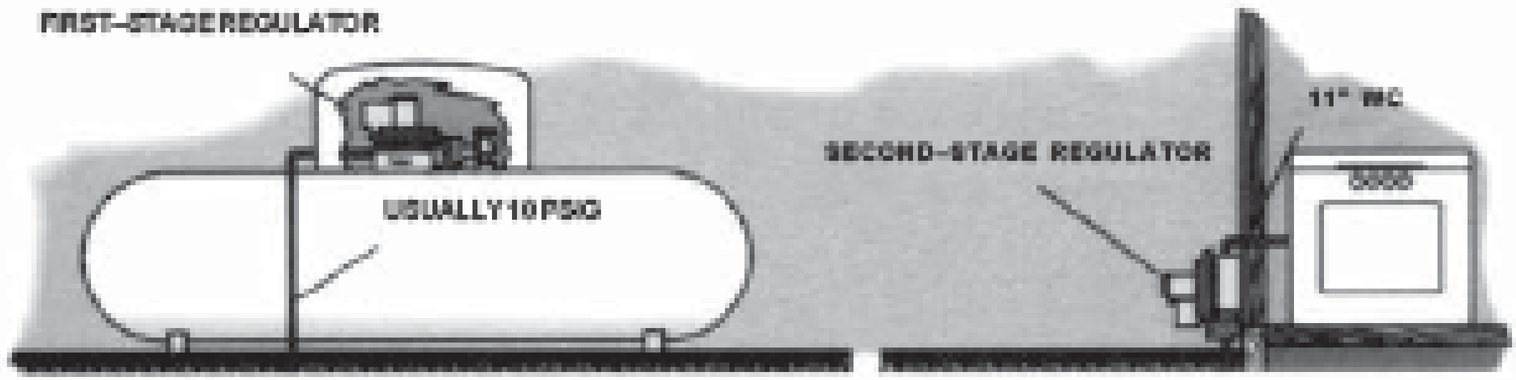
Lower Installation Costs - Smaller pipe or tubing can be used between the first and second-stage regulators due to the higher pressure, thus reducing installation and piping material costs.

Freezeups - Two-stage systems reduce problems due to regulator freezeups caused by excessive water in gas. Larger orifices make it more difficult for ice to form and block the passage area. The expansion of gas at two different orifices in a two-stage system greatly reduces the “refrigeration effect” that causes freezeups.

Flexibility of Installation - A high pressure regulator can feed a number of low pressure regulators, thus enabling the addition of appliances in the future to the same pressure line without affecting their individual performance.

Fewer Trouble Calls - With two-stage regulation, you can expect fewer trouble calls due to pilot outage or burner adjustment. This means higher appliance efficiency, lower service costs and better customer relations.

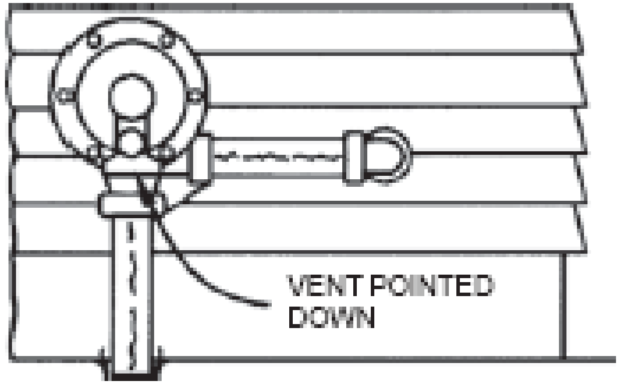
REGULATOR INSTALLATION



TWO-STAGE REGULATION

Two Regulators, one at tank and one at building, reduce pressure down to burner pressure (11" w.c.)

Regulator Vents



<u>Outdoor Installations</u>

A regulator installed outdoors without a protective hood must have its vent pointed vertically down, as shown in the drawing.

-The regulator should be at least 18 inches above ground.

-Do not install the regulator where there can be excessive water accumulation or ice formation, such as directly beneath a downspout, gutter or roofline.

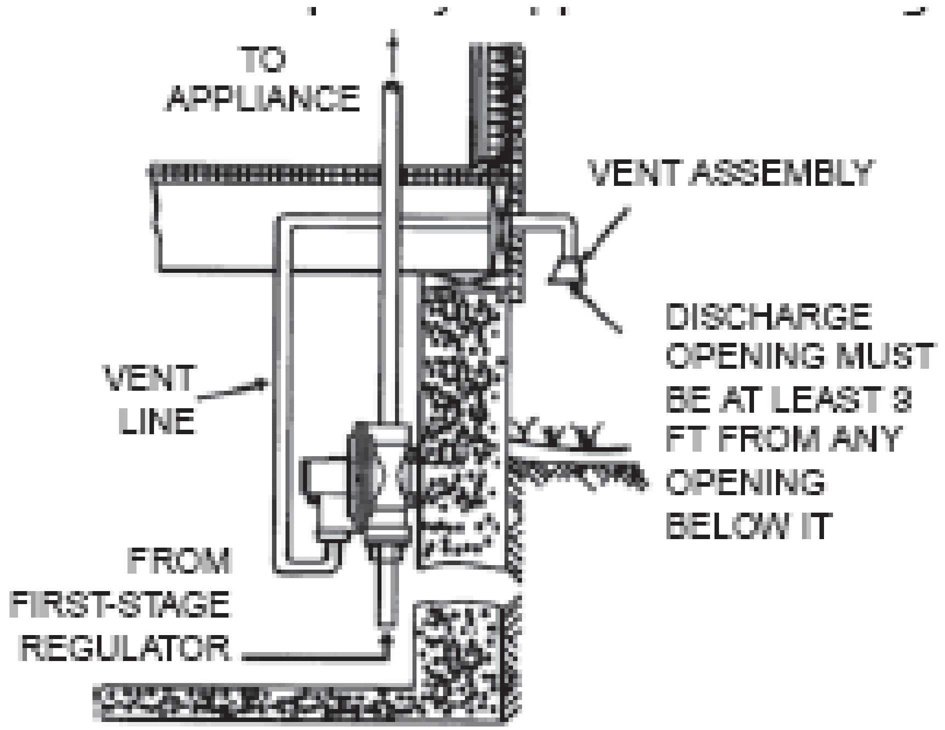
- All vent openings must be at least three horizontal feet from any building opening and no less than five feet in any direction from any source of ignition, openings into direct vent appliances or mechanical ventilation intakes.

- Horizontally mounted regulators, such as on single cylinder installations, must be installed underneath a protective cover. On ASME tank installations with the regulator installed under the tank dome, the regulator vent should slope slightly down enough to allow any condensation to drain from the spring case. The regulator vent should be positioned far enough back from the tank dome slot so that it is protected from the weather. The hood should be kept closed.

Indoor Installations

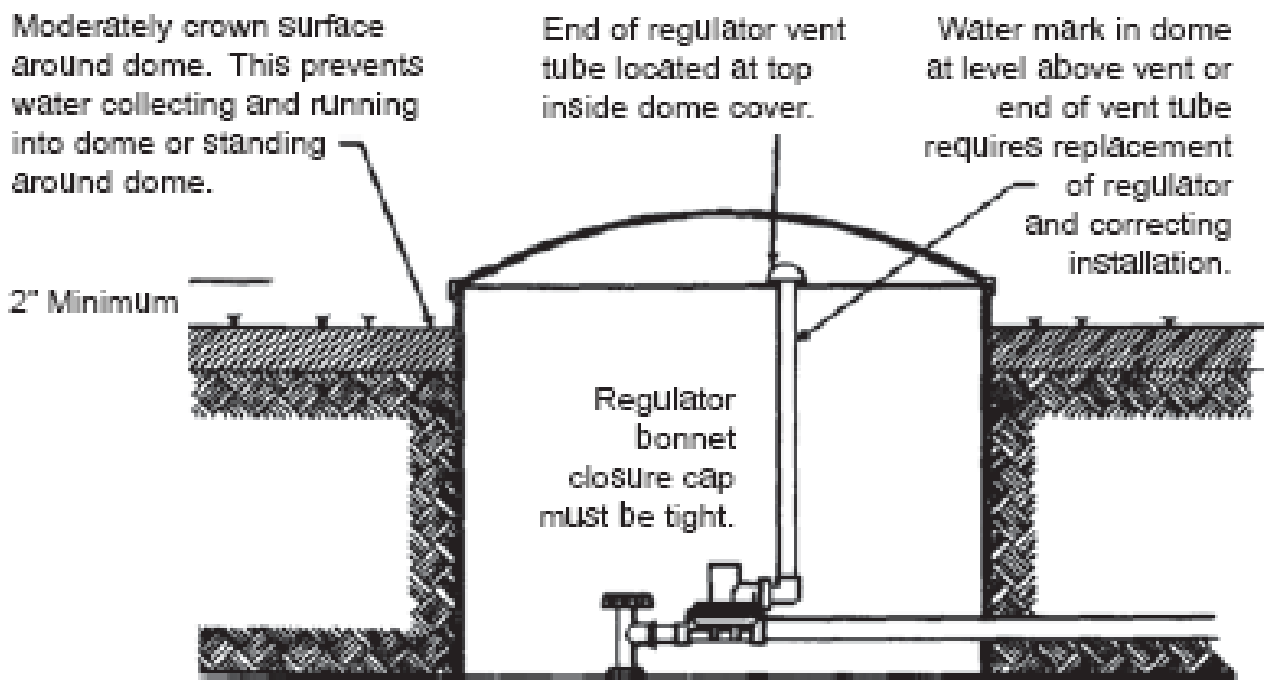
In a fixed pipe system, regulators installed indoors require a vent line to the outside air.

A screened vent assembly must be used at the end of the vent line. The vent assembly position and location precautions are the same as for regulator vents. The vent line must be the same size as the regulator vent and adequately supported. See Figure below.



Underground Tanks

A vent tube is required on these installations to prevent water from entering the regulator's spring case. The vent tube connects to the regulator vent and terminates above any possible water level, see Figure below. Be sure that the ground slopes away from the tank dome as illustrated. See Figure below.



Part Four

Natural Gas
Vs
LP-Gas

		NG	Propane	Butane	
Chemical formula		CH4	C3H8	C4H10	
Boiling point of liquid at atmospheric pressure		- 162 °C	-42 °C	0 °C	
Specific Gravity of vapor (Air = 1)		0.6	1.53	2.0	
Specific Gravity of liquid (Water = 1)		0.6	0.51	0.58	
Calorific value @ 60 °F (15°C)	BTU/CFT	1012	2516	3280	3127
	BTU/ m³	35901	88906	115901	110495
	Kcal / m³	9047	22,404	29,270	27845
Latent heat of vaporization	Kcal/Kg		785	808	
Liquid weight	Kg / Liter		0.508	0.576	
Vapor volume from 1 liter of liquid at 15 °C	m³		0.272	0.234	
Vapor volume from 1 kg of liquid at 15 °C	m³		0.534	0.406	
Combustible limits % of gas in Air		5 - 15	2.4 - 9.6	1.9 - 8.6	
Amount of air required to burn 1 m3 of gas	m³	9.53	23.86	31.02	
Ignition temperature in air	°C	650	490 - 550	480 - 540	
Maximum flame temperature in air	°C	1964	1980	1991	
Octane Number		100	Over 100	92	

All data is approximate. For actual properties of any particular batch, contact your fuel supplier.

		NG	Propane	Butane
Chemical formula		**CH_4**	**C_3H_8**	**C_4H_{10}**
Boiling point of liquid at atmospheric pressure		**- 162 °C**	**-42 °C**	**0 °C**
Specific Gravity of vapor (Air = 1)		**0.6**	**1.53**	**2.0**
Specific Gravity of liquid (Water = 1)		**0.6**	**0.51**	**0.58**
Calorific value @ 60 °F (15°C)	BTU/CFT Kcal / m^3	**1012** **9005**	**2516** **22,390**	**3280** **29,190**
Latent heat of vaporization	Kcal/Kg		**785**	**808**
Liquid weight	Kg / Liter		**0.508**	**0.576**
Vapor volume from 1 liter of liquid at 15 °C	m^3		**0.272**	**0.234**
Vapor volume from 1 kg of liquid at 15 °C	m^3		**0.534**	**0.406**
Combustible limits % of gas in Air		**5 - 15**	**2.4 - 9.6**	**1.9 - 8.6**
Amount of air required to burn 1 m3 of gas	m^3	9.53	23.86	31.02
Ignition temperature in air	°C	**650**	**490 - 550**	**480 - 540**
Maximum flame temperature in air	°C	**1964**	**1980**	**1991**
Octane Number		**100**	**Over 100**	**92**

All data is approximate. For actual properties of any particular batch, contact your fuel supplier.

Several characteristics affect Liquified Petroleum Gas (LPG) as a replacement fuel.

These include :

1 - Flame Velocity and Color
2 - Specific Gravity
3 - Calorific Value
4 - BTU Measurement (Wobbe Index)

1 - Flame Velocity and Color

Because of the different number of carbon atoms in propane, propane-air mixtures produce a flame that is more yellow in color than that of natural gas. However, the yellow tips are not of any consequence and do not affect burner operation or efficiency. Flame velocities of LPG are near equal to that of natural gas. Therefore, there is no significant flame lift difference between natural gas and propane-air mixtures.

2 - Specific Gravity

The density of gas, relative to air, is called specific gravity. The specific gravity of air is defined as 1. Since propane gas has a specific gravity of 1.5, propane-air mixtures have a specific gravity of greater than 1.

3 - The Wobbe Index, a critical factor when analyzing LPG-Air plant requirements, is a function of gas quality and allows matching one gas (in this case, natural gas) to a replacement gas (in this case, LPG-Air). If the two different gases have an identical Wobbe Index, they will produce an equal amount of heat and combustion products and will require the same amount of combustion air. Burners, adjusted for a specific calorific value and fitted with a replacement orifice to match a lower Wobbe Index, result in minor combustion changes. Substituting a gas for one with a higher Wobbe Index, generally allows a narrow acceptance range. Flame characteristics determine the acceptance range for the replacement gas.

Wobbe Index

Goffredo Wobbe , Physicist , Bologna, Italy, 1927

1. The heat output of a burner at constant gas pressure at constant orifice size is proportional to the flow volume per time.
   (The longer you run the burner, the more heat is being put out.)

2. The flow velocity through a given orifice size at constant pressure is proportional to the specific gravity (SG) of a gas.
   (The lighter a gas molecule is, the more molecules can pass through a fixed-size orifice.)

3. The calorific value (CV) of a gas is proportional to its specific gravity (SG).

NG 1000 BTU/ft3 SG=0.61 à 1640

C3 2516 BTU/ft3 SG=1.53 à 1644

C4 3280 BTU/ft3 SG=2.00 à 1640

Combining the three ideas , we can come up with a formula that allows us to compare the flow characteristics of two gasses.

If we know their CVs or SGs, we can determine whether they produce similar heat outputs when used with the same orifice.

Mr. Wobbe's Formula

$$\text{Wobbe Index} = \frac{\text{Calorific Value}}{\sqrt{\text{SG}}}$$

He decided to keep the number dimension –less to avoid confusion with CV.

Wobbe Index

Wobbe Index Explanation (from American Gas Association Bulletin No. 36)

The Wobbe number, or Wobbe index, of a fuel gas is found by dividing the high heating value of the gas in Btu per standard cubic foot by the square root of its specific gravity with respect to air. The higher a gases' Wobbe number, the greater the heating value of the quantity of gas that will flow though a hole of a given size in a given amount of time. It is customary to give a Wobbe number without units–even though it has the dimensions Btu per scf–because to do so would lead to confusion with the volumetric heating value of the gas.

In almost all gas appliances, the flow of gas is regulated by making it pass through a hole or orifice. **The usefulness of the Wobbe number is that for any given orifice, all gas mixtures that have the same Wobbe number will deliver the same amount of heat.** Pure methane has a Wobbe number of 1363; natural gas as piped to homes in the United States typically has a Wobbe number between 1310 and 1390.

Wobbe Index of Natural Gas

$$\text{Wobbe Index} = \frac{\text{Calorific Value}}{\sqrt{SG}}$$

$$\text{Wobbe Index} = \frac{1000\ [BTU / cuft]}{\sqrt{0.61}} = \frac{1000}{0.781}$$

Wobbe Index of Natural Gas = **1280**

Wobbe Index of Natural Gas

SG	0.59	0.6	0.61	0.62
Sqrt(SG)	0.7681	0.7746	0.7810	0.7874
CV	Wobbe Index			
950	1237	1226	1216	1207
980	1276	1265	1255	1245
1000	1302	1291	1280	1270
1050	1367	1356	1344	1334

Wobbe Index of LPG/Air Mix

SG_{SNG}	=	1.28 to 1.32
$\sqrt{1.28}$	=	1.1313
$\sqrt{1.32}$	=	1.1489
CV_{SNG}	=	1292 BTU/cuft @ 1.28
	to	1476 BTU/cuft @ 1.32
$Wobbe_{SNG}$	=	1142 @ 1.28
	to	1284 @ 1.32

Typical Mixed Gas Settings

SG $_{(SNG)}$ = 1.28 to 1.32 , Specific Gravity

CV $_{(SNG)}$ = 1292 BTU/cuft @ 1.28 , Calorific Value

to 1476 BTU/cuft @ 1.32

Ratio $_{(SNG)}$ = 51/49 Vapor/Air @ 1.28
to 58/42 Vapor/Air @ 1.32

SNG = Synthetic Natural Gas

Consider the Wobbe Index !

$Wobbe_{SNG}$	=	1142 @ 1.28
	to	1284 @ 1.32
CV_{NG}	=	1000 BTU/cuft
SG_{NG}	=	0.61
$Wobbe_{NG}$	=	1280

Wobbe Index changes :

Natural Gas changes due to : Seasonal Changes or the Source may change

LPG Mixture due to : Propane / Butane Composition

How much Wobbe Change is Acceptable

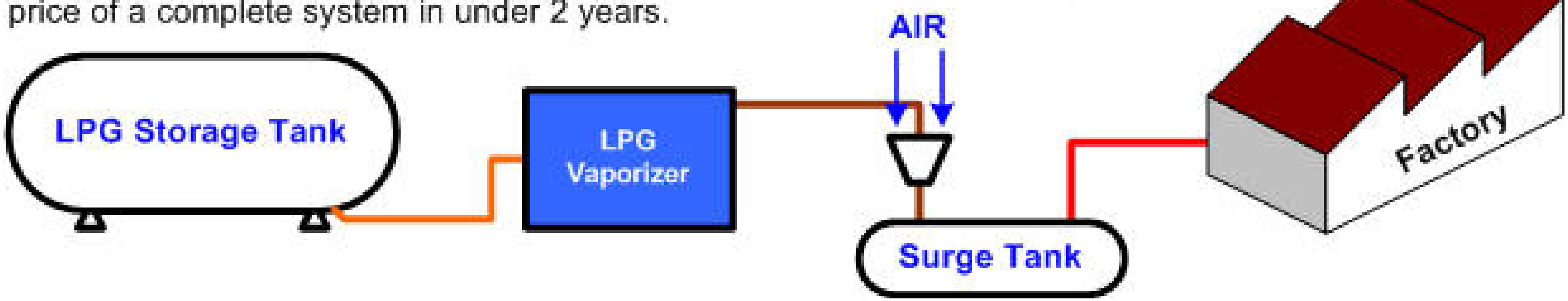
- Less than 5% deviation is desired
- Depending on how much SNG you have in your PANG*, the WobbeSNG should be maintained at better than +/- 10%

*PANG = Propane Air Natural Gas

Typical max. LP/Air is 50% of total to maintain the SGPANG lighter than Air.

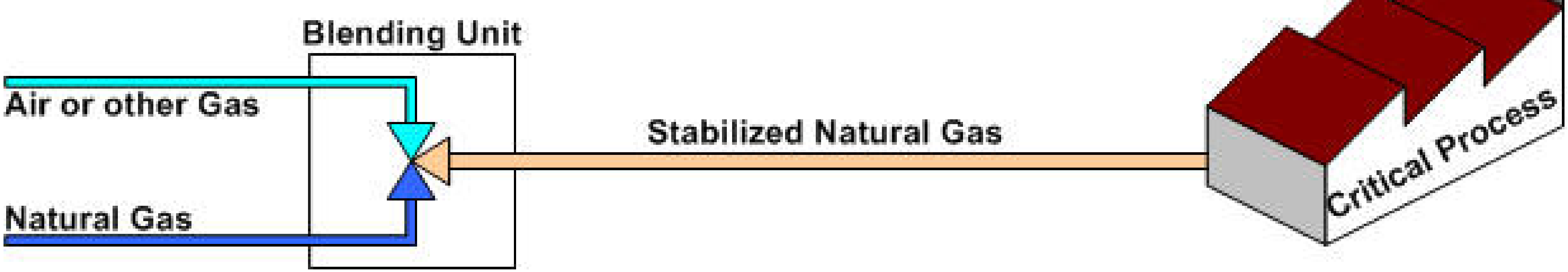
Create LP/Air Mixture (Synthetic Natural Gas) to replace Natural Gas

If the supply of Natural Gas is interrupted, these systems produce a mixture of LP Vapor and Air with properties that are equivalent to those of Natural Gas. This allows users to continue using their Natural Gas equipment without having to switch to equipment that can handle other fuel sources (like fuel oil, coal, etc.). Commercial and industrial users can take advantage of steep discount on Natural Gas, offered by their gas utility company, if they agree to be curtailed when demand on Natural Gas exceeds supply. These discounts are usually sufficient to amortize the purchase price of a complete system in under 2 years.

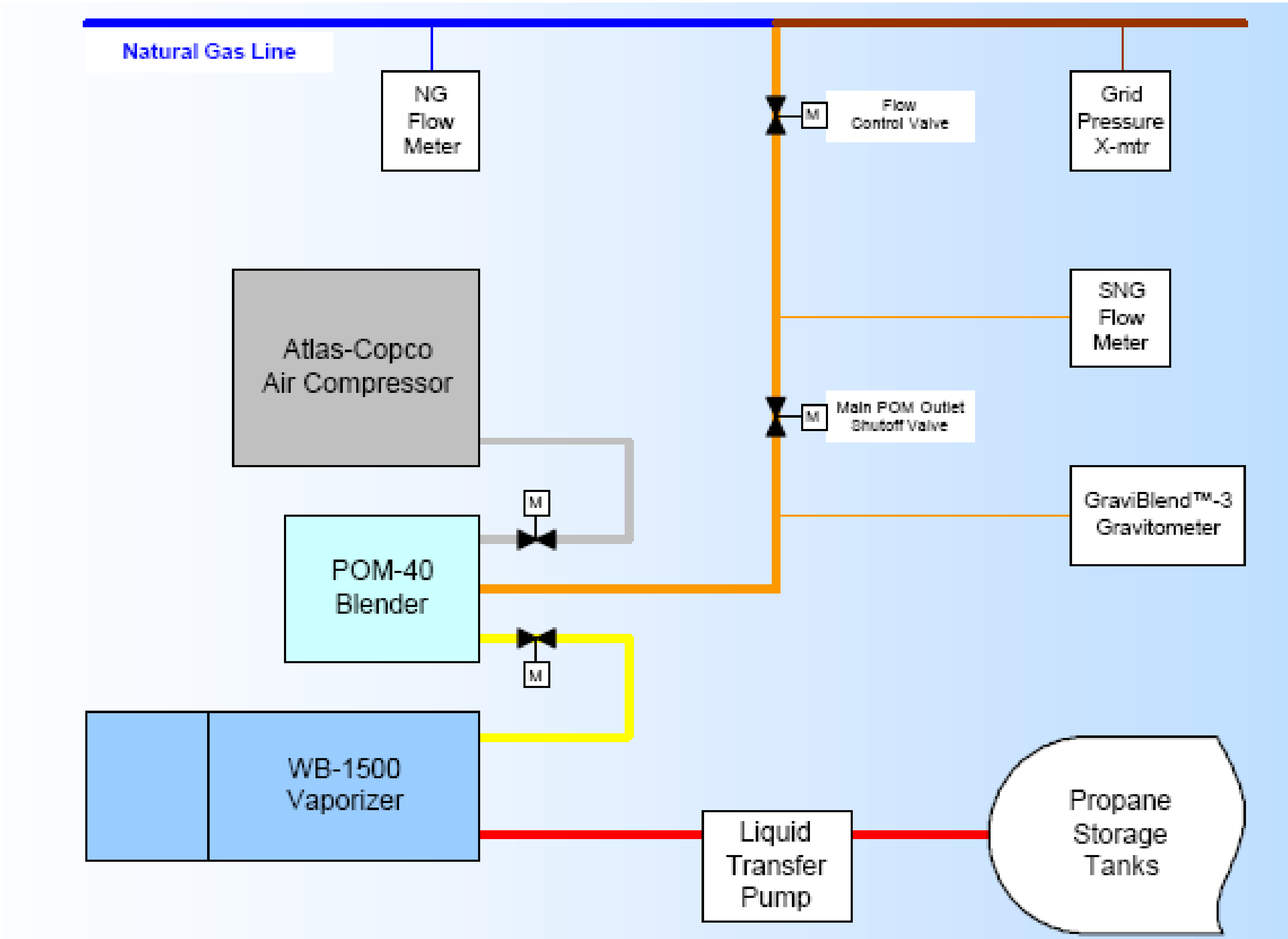


Conditioning of Natural Gas to obtain consistent Calorific Values

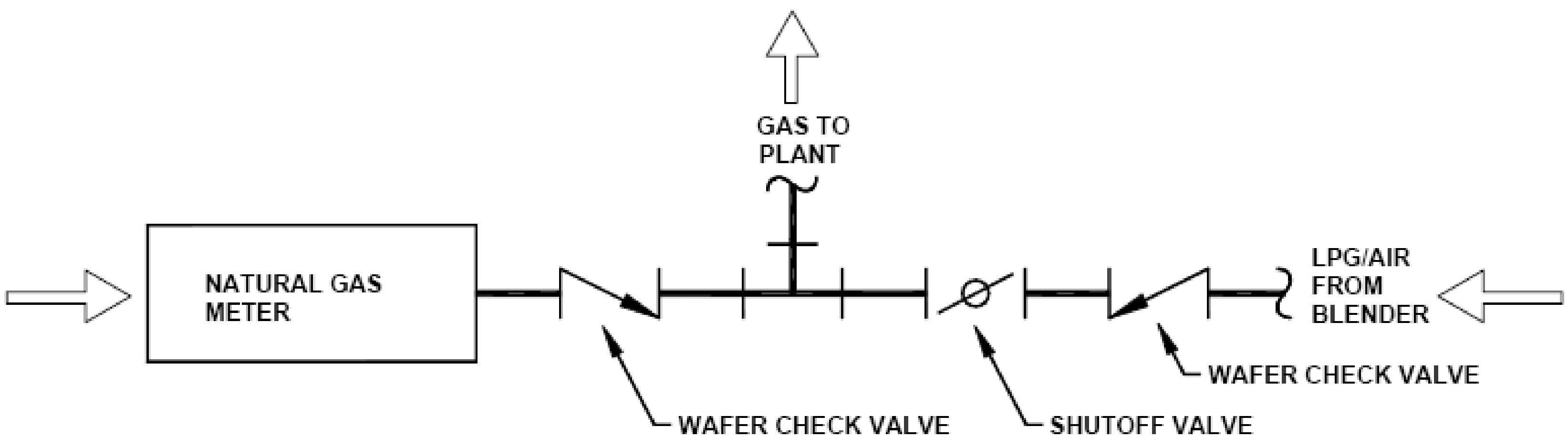
In certain critical manufacturing processes, even small fluctuations in the Calorific Value of Natural Gas can create wide swings of burner output temperatures, resulting in product quality problems, or even complete loss of the manufacturing batch. AES Gas Blending Systems take the Natural Gas as supplied by the utility company and blend it with Air, Nitrogen, LP, or another conditioning gas. The blending ratio is variable, and is automatically controlled through sensors in the output stream of the system, measuring the actual gas properties. The result is Natural Gas with consistent, pre-defined and very well repeatable heating values. Examples of processes that can benefit from this technology include glass kilns, ceramic kilns, heat treatment plants, etc.



PeakShaving System Components



Natural Gas to SNG Tie-In Detail



TYPICAL TIE-IN DETAIL

LPG AS VEHICLE FUEL

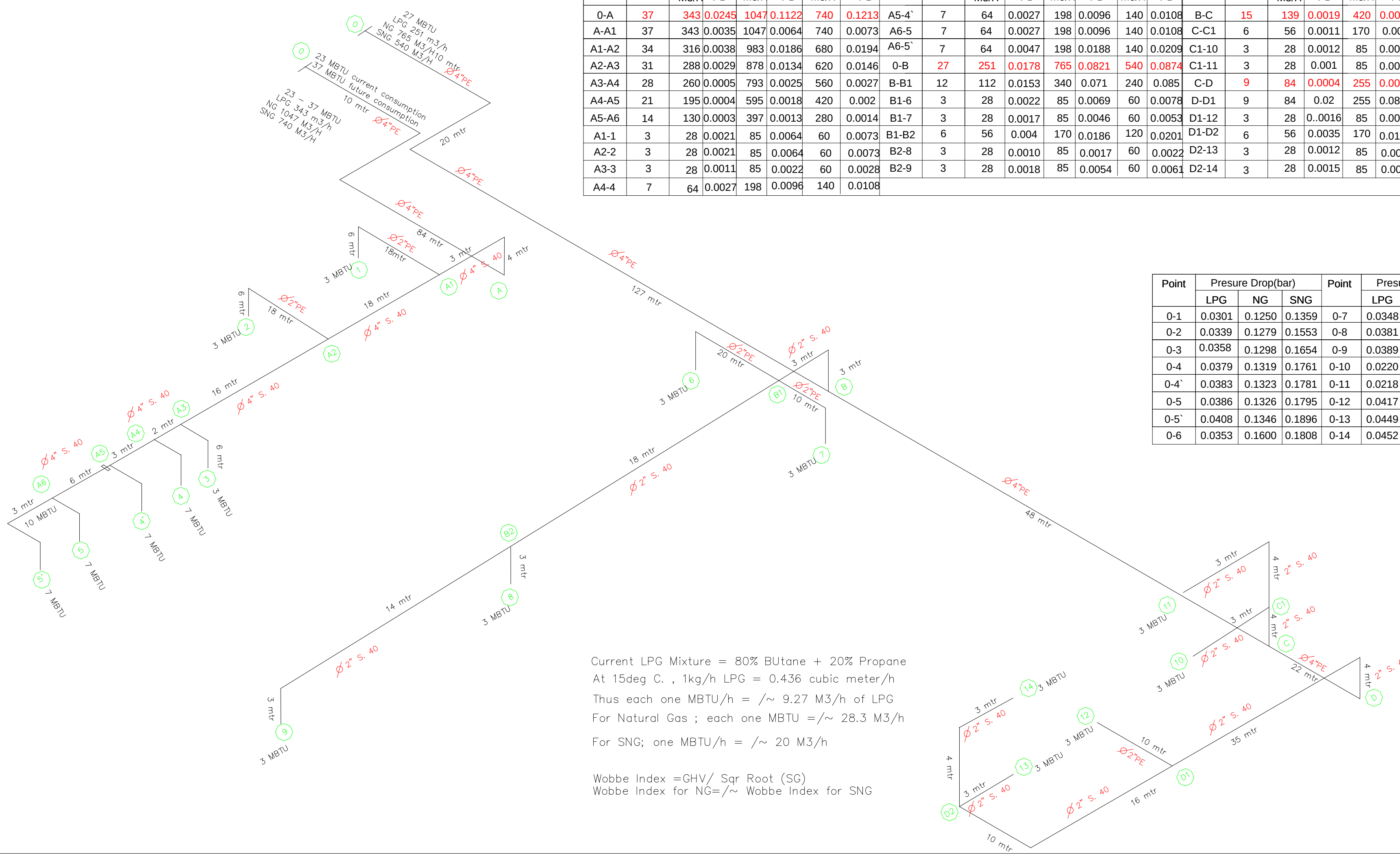
ADVANTAGES OVER CNG

- LPG kit is 30 – 40 % cheaper than CNG.
- No significant power loss as in CNG.
- LPG tank is very light as compared to CNG.
- Filling time of LPG is up to 40 liters / minute , CNG takes a long time to fill.
- LPG can easily be available in almost every patrol station
- Distance covered after filling tank once is almost double in LPG than CNG.

Green Gas
OIL & GAS TECHNOLOGY

Part 5

Case Study // Design of a complete LPG system with LPG / SNG / NG distribution Network



Point	CONSUMPTION / PRESSURE DROP						
	MBTU	LPG		NG		SNG	
		M3/H	PD	M3/H	PD	M3/H	PD
0-A	37	343	0.0245	1047	0.1122	740	0.1213
A-A1	37	343	0.0035	1047	0.0064	740	0.0073
A1-A2	34	316	0.0038	983	0.0186	680	0.0194
A2-A3	31	288	0.0029	878	0.0134	620	0.0146
A3-A4	28	260	0.0005	793	0.0025	560	0.0027
A4-A5	21	195	0.0004	595	0.0018	420	0.002
A5-A6	14	130	0.0003	397	0.0013	280	0.0014
A1-1	3	28	0.0021	85	0.0064	60	0.0073
A2-2	3	28	0.0021	85	0.0064	60	0.0073
A3-3	3	28	0.0011	85	0.0022	60	0.0028
A4-4	7	64	0.0027	198	0.0096	140	0.0108

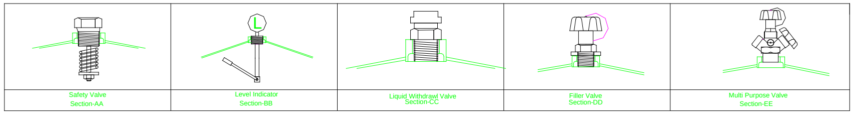
Point	CONSUMPTION / PRESSURE DROP						
	MBTU	LPG		NG		SNG	
		M3/H	PD	M3/H	PD	M3/H	PD
A5-4`	7	64	0.0027	198	0.0096	140	0.0108
A6-5	7	64	0.0027	198	0.0096	140	0.0108
A6-5`	7	64	0.0047	198	0.0188	140	0.0209
0-B	27	251	0.0178	765	0.0821	540	0.0874
B-B1	12	112	0.0153	340	0.071	240	0.085
B1-6	3	28	0.0022	85	0.0069	60	0.0078
B1-7	3	28	0.0017	85	0.0046	60	0.0053
B1-B2	6	56	0.004	170	0.0186	120	0.0201
B2-8	3	28	0.0010	85	0.0017	60	0.0022
B2-9	3	28	0.0018	85	0.0054	60	0.0061

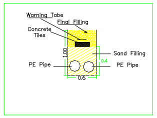
Point	CONSUMPTION / PRESSURE DROP						
	MBTU	LPG		NG		SNG	
		M3/H	PD	M3/H	PD	M3/H	PD
B-C	15	139	0.0019	420	0.0083	300	0.0094
C-C1	6	56	0.0011	170	0.005	120	0.0053
C1-10	3	28	0.0012	85	0.0025	60	0.0031
C1-11	3	28	0.001	85	0.0036	60	0.0039
C-D	9	84	0.0004	255	0.0017	180	0.0024
D-D1	9	84	0.02	255	0.0878	180	0.0958
D1-12	3	28	0..0016	85	0.0043	60	0.005
D1-D2	6	56	0.0035	170	0.0132	120	0.0147
D2-13	3	28	0.0012	85	0.0025	60	0.0031
D2-14	3	28	0.0015	85	0.0036	60	0.0039

Point	Presure Drop(bar)			Point	Presure Drop(bar)		
	LPG	NG	SNG		LPG	NG	SNG
0-1	0.0301	0.1250	0.1359	0-7	0.0348	0.1577	0.1783
0-2	0.0339	0.1279	0.1553	0-8	0.0381	0.1734	0.1923
0-3	0.0358	0.1298	0.1654	0-9	0.0389	0.1771	0.1955
0-4	0.0379	0.1319	0.1761	0-10	0.0220	0.0980	0.1058
0-4`	0.0383	0.1323	0.1781	0-11	0.0218	0.1000	0.1066
0-5	0.0386	0.1326	0.1795	0-12	0.0417	0.1842	0.2006
0-5`	0.0408	0.1346	0.1896	0-13	0.0449	0.1956	0.2134
0-6	0.0353	0.1600	0.1808	0-14	0.0452	0.1967	0.2143

Current LPG Mixture = 80% BUtane + 20% Propane
At 15deg C. , 1kg/h LPG = 0.436 cubic meter/h
Thus each one MBTU/h = /~ 9.27 M3/h of LPG
For Natural Gas ; each one MBTU =/~ 28.3 M3/h
For SNG; one MBTU/h = /~ 20 M3/h

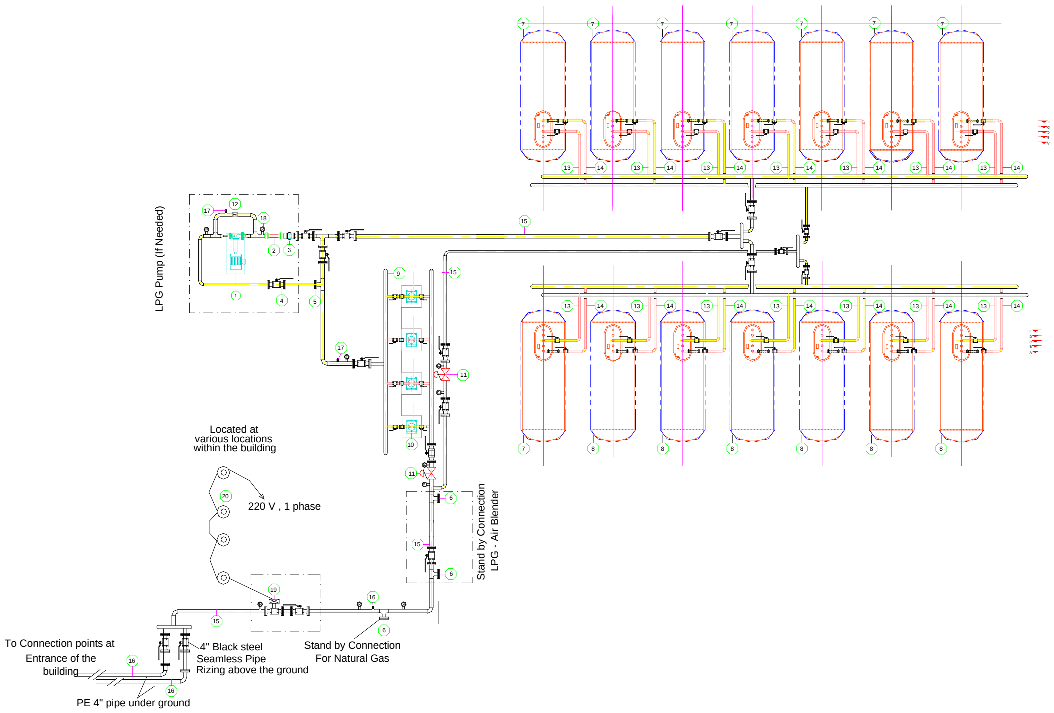
Wobbe Index =GHV/ Sqr Root (SG)
Wobbe Index for NG=/~ Wobbe Index for SNG





Main Feeding Line Burried under ground

1	LPG Pump (If Needed)
2	Flexible Connetion
3	Strainer
4	Ball Valve
5	Flanges
6	Blined Flange
7	LPG Tank 6400 Liters
8	LPG Tank 5000 Liters
9	4", Seamless Pipe sch80
10	Elec. Vaporizer XP160 b y Alga-SdI / USA of capacity of 320 kg/h Total capacity of vaporizers =1280 kg/h = 150.6 % of max load MAX LOAD = 850 KG given by burners supplier "Proffesional Engineers"
11	First Stage Regulator Fisher 99-903p with total capacity 44.2 MBTU = 110.7 % of max load MAX LOAD = 850 KG given by burners supplier "Proffesional Engineers"
12	One Way Valve
13	2" Seamless Pipe sch40
14	1" seamlless Pipe sch40
15	4" Seamless Pipe sch40
16	4" PE Pipe 80 or 100
17	Safety Valve
18	Pressure Gauge
19	Solenoid Valve
20	Emerg. Push Button



LPG Tanks Location