CHAPTER C17

FUEL GAS DISTRIBUTION PIPING SYSTEMS

Michael Frankel, CIPE
Utility Systems Consultants
Somerset, N.J.

INTRODUCTION

Fuel gas provides light and heat energy in sufficient volume and pressure required for the satisfactory operation of all connected devices. This chapter will discuss natural gas and propane from the site property line and within a facility. For natural gas transportation systems delivering fuel gas to the site, refer to Chap. C6.

FUEL GAS DESCRIPTION

Many gases found throughout the world are capable of being used as a fuel gas. Where available, two major fuel gases, natural gas (NG) and liquefied petroleum gas (LPG), are most often used. Other gases are used in instances where lower cost and greater availability make them attractive. Refer to Table C17.1 for the physical and combustion properties of the most commonly available fuel gases.

NG and LPG are naturally occurring hydrocarbon compounds obtained from the separation of crude oil or gas mixtures at producing wells, or as a byproduct of the oil refining process. NG is primarily composed of methane with minor, varying percentages of other gases. These differences result in variations in heating content. LPG is a term applied to a group of hydrocarbons such as propane, butane, isobutane, and pentane, or various mixtures of each. Propane and butane are the principal constituents of LPG, with propane being the most common. Table C17.2 lists the properties of only NG and propane in more detail. Since NG and LPG are odorless, an odorfant is added to make detection of gas possible for reasons of safety.

Variations occur in the hydrocarbon mixtures and Btu content that make up NG and LPG obtained from various suppliers. The values presented here are average values and sufficiently accurate for the design of these systems.

TABLE C17.1 Physical and Combustion Properties of Commonly Available Fuel Gases

	Heating value				Heat release, Btu[3]				
	Btu/cu ft[1]		Btu/lb[2]					Density, lb per cu ft	Specific volume cu ft/lb
Gas name	Gross	Net	Gross	Net	Per cu ft air	Per lb air	Specific gravity		
1 Acetylene	1498	1447	21,569	20,837	125.8	1677	0.91	.07	14.4
2 Blast Furnace Gas	92	92	1178	1178	135.3	1804	1.02	.078	12.8
3 Butane	3225	2977	21,640	19,976	105.8	1411	1.95	.149	6.71
4 Butylene (Butene)	3077	2876	20,780	19,420	107.6	1435	1.94	.148	6.74
5 Carbon Monoxide	323	323	4368	4368	135.7	1809	0.97	.074	13.5
6 Carburetted Water Gas	550	508	11,440	10,566	119.6	1595	0.63	.048	20.8
7 Coke Oven Gas	574	514	17,048	15,266	115.0	1533	0.44	.034	29.7
8 Digester (Sewage) Gas	690	621	11,316	10,184	107.6	1407	0.80	.062	16.3
9 Ethane	1783	1630	22,198	20,295	106.9	1425	1.06	.060	12.5
10 Hydrogen	325	275	61,084	51,628	136.6	1821	0.07	.0054	186.9
11 Methane	1011	910	23,811	21,433	106.1	1415	0.55	.042	23.8
12 Natural (Birmingham, AL)	1002	904	21,844	19,707	106.5	1420	0.60	.046	21.8
13 Natural (Pittsburgh, PA)	1129	1021	24,161	21,849	106.7	1423	0.61	.047	21.4
14 Natural (Los Angeles, CA)	1073	971	20,065	18,158	106.8	1424	0.70	.054	18.7
15 Natural (Kansas City, MO)	974	879	20,259	18,283	106.7	1423	0.63	.048	20.8
16 Natural (Groningen, Netherlands)	941	849	19,599	17,678	111.9	1492	0.64	.048	20.7
17 Natural (Midlands Grid, U.K.)	1035	902	22,500	19,609	105.6	1408	0.61	.046	21.8
18 Producer (Wellman-Galusha)	167	156	2650	2476	128.5	1713	0.84	.065	15.4
19 Propane	2572	2365	21,500	19,770	108	1440	1.52	.116	8.61
20 Propylene (Propene)	2332	2181	20,990	19,630	108.8	1451	1.45	.111	9.02
21 Sasol (South Africa)	500	443	14,550	13,016	116.3	1551	0.42	.032	31.3
22 Water Gas (bituminous)	261	239	4881	4469	129.9	1732	0.71	.054	18.7

[1] 1 cu ft = 0.0283 m^3.
[2] 1 lb = 0.453 kg.
[3] 1 Btu = 0.252 kCal.

TABLE C17.2 Average Physical Properties of Natural Gas and Propane

	Propane	Natural gas (methane)
Formula	C_3H_8	CH_4
Molecular Weight	44.097	16.402–16.402
Melting (or Freezing) Point, °F	−305.84	−300.54
Boiling Point, °F	−44	−258.70
Specific Gravity of Gas (Air = 1.00)	1.52	0.60
Specific Gravity of Liquid 60°F/60°F (Water = 1.00)	0.588	0.30
Latent Heat of Vaporization at Normal Boiling Point Btu/lb	183	245
Vapor Pressure, lb/sq in. Gauge at 60°F (15.6°C)	92	
Pounds per Gallon of Liquid at 60°F	4.24	2.51
Gallons per lb of Liquid at 60°F	0.237	
Btu per lb of Gas (gross)	21591	23000
Btu per cu ft Gas at 60°F and 30″ Hg	2516	1050 ±
Btu per gal of Gas at 60°F	91547	
Cu ft of Gas (60°F, 30″ Hg)/Gal of Liquid	36.39	59.0
Cu ft of Gas (60°F, 30″ Hg)/Lb of Liquid	8.58	23.6
Cu ft of Air Required to Burn 1 cu ft Gas	23.87	9.53
Flame Temperature, °F	3595	3416
Octane Number (Iso-Octane = 100)	125	
Flammability Limit in Air—Upper	9.50	15.0
Flammability Limit in Air—Lower	2.87	5.0

1″ HG = 3.37 kPa.
60°F = 15.6°C.
1 lb = 0.453 kg.
1 gal = 4.55 liters.
1 cu ft = 0.453 kg.

CODES AND STANDARDS

The principal codes, standards, and regulations governing the manufacture, design, installation, and testing of NG and LPG systems are as follows:

ANSI/NFPA 30	Flammable and Combustible Liquids Code
ANSI Z223.1/NFPA 54	National Gas Code
NFPA 58	Standard for the Storage and Handling of Liquefied Petroleum Gases
ANSI Z83.3	Standard for Gas Utilization Equipment in Large Boilers
ANSI/UL 144	Pressure Regulating Valves for LP Gas
AGA	American Gas Association
SBCCI	International Fuel Gas Code
ASME Section VIII	Pressure Vessels
	Local utility company rules and regulations.

Some insurance carriers may have standards that in many aspects may be more stringent than those listed.

SYSTEM OPERATING PRESSURES

The pressure in a site main is the same as that existing in the public utility mains since pressure is not reduced until the point where the facility meter is installed. The pressure in the main generally is in the range of 25 to 50 pounds per square inch gauge (psig) or 172.5 to 345 kilo Pascals (kPa). Pressures inside buildings are often very low. Refer to Table C17.3 for a conversion of low fuel gas pressures into various Inch Pound (IP) and International System (SI) units. (SI units are referred to as metric units.)

The maximum allowable system operating pressure of fuel gas when installed inside a building is generally governed by NFPA 54, unless local codes or insurance carriers have more stringent requirements. NG systems are not permitted to exceed 5 psig (34.5 kPa) unless all of the following conditions are met:

1. Local authorities permit a higher pressure.
2. All piping is welded.

TABLE C17.3 Conversion of Gas Pressure to Various Designations, 60°F (15.6°C)

	Equivalent inches		Pressure per square inch		Equivalent inches		Pressure per square inch		
kPa	Water	Mercury	Pounds	Ounces	Water	Mercury	Pounds	Ounces	kPa
0.002	0.01	0.007	0.0036	0.0577	8.0	0.588	0.289	4.62	2.0
0.05	0.20	0.015	0.0072	0.115	9.0	0.662	0.325	5.20	2.2
0.07	0.30	0.022	0.0108	0.173					
0.10	0.40	0.029	0.0145	0.231	10.0	0.74	0.361	5.77	2.5
					11.0	0.81	0.397	6.34	2.7
0.12	0.50	0.037	0.0181	0.239	12.0	0.88	0.433	6.92	3.0
0.15	0.60	0.044	0.0217	0.346	13.0	0.96	0.469	7.50	3.2
0.17	0.70	0.051	0.0253	0.404					
0.19	0.80	0.059	0.0289	0.462	13.6	1.00	0.491	7.86	3.37
0.22	0.90	0.066	0.0325	0.520	13.9	1.02	0.500	8.00	3.4
					14.0	1.06	0.505	8.08	3.5
0.25	1.00	0.074	0.036	0.577					
0.3	1.36	0.100	0.049	0.785	15.0	1.10	0.542	8.7	3.7
0.4	1.74	0.128	0.067	1.00	16.0	1.18	0.578	9.2	4.0
0.5	2.00	0.147	0.072	1.15	17.0	1.25	0.614	9.8	4.2
0.72	2.77	0.203	0.100	1.60	18.0	1.33	0.650	10.4	4.5
0.76	3.00	0.221	0.109	1.73	19.0	1.40	0.686	10.9	4.7
1.0	4.00	0.294	0.144	2.31					
					20.0	1.47	0.722	11.5	5.0
1.2	5.0	0.368	0.181	2.89					
1.5	6.0	0.442	0.217	3.46	25.0	1.84	0.903	14.4	6.2
1.7	7.0	0.515	0.253	4.04	27.2	2.00	0.975	15.7	6.7
	0.7				27.7	2.03	1.00	16.0	6.9

3. The pipe runs are enclosed for protection or located in a well-ventilated space that will not permit gas to accumulate.
4. The pipe is run inside buildings or areas and is used only for industrial processes, research purposes, within warehouses, or within boiler and/or mechanical equipment rooms.

LPG pressures up to 20 psig (138 kPa) are permitted only if all of the following conditions are met:

1. Buildings are used exclusively for industrial purposes or as experimental laboratories, or are buildings with similar use requirements.
2. The building is constructed in accordance with Chapter 7, NFPA 58, Fuel Gas Code.

NATURAL GAS

Natural gas is purchased from either of two sources. The first, restricted to very large users of gas, is from a transportation gas company where the gas is directly purchased by the facility from the point where gas is originated. The second is from a public utility obligated to provide gas to every customer that requests this service. As part of this service, the utility company usually supplies and installs the service line free of charge from the utility main, in addition to providing, also at no cost, a regulator/meter assembly in or adjacent to the building.

Rarely, the utility company does not have a main in the vicinity of the project. An installation fee may be charged if the utility company regulations concerning the time of payback from expected revenue do not justify the cost of installing the service. The same might be true if the volume of gas for a commercial or industrial facility is considered too small. It would then be the responsibility of the owner to pay for the design and installation of the complete private site service and meter assembly in conformity with utility company regulations.

Requirements of various utility companies differ regarding the placement of the meter assembly. It could be installed either in an underground, exterior meter pit; at an aboveground exterior location exposed to the weather; or inside the building in a well-ventilated area or mechanical equipment room.

There are several different types of service that a utility company may provide, each with a different cost (or rate). Specific types of service may be unavailable or known by different names in various localities. They are:

1. *Firm Service.* This type of service provides a constant supply of gas under all conditions without exception.
2. *Interruptible Service.* This type of service allows the utility company to stop the gas supply to the facility under predetermined conditions, and to start it again when these conditions no longer exist.
3. *Light or Heavy Process Service.* This type of service is provided for large quantities used for industrial or process facilities.
4. *Commercial/Industrial Service.* This type of service is provided for heating and cooling system loads for larger facilities.
5. *Transportation Gas Service.* This is purchased directly from a company other

than the public utility, with the gas carried to the site by the public utility company mains.

The following criteria and information should be obtained in writing from the public utility company when requesting service:

1. Btu content of the gas provided
2. Minimum pressure of the gas at the outlet of the meter assembly
3. Extent of the installation work done by the utility company, and the point of connection by the facility construction contractor
4. The location of the utility supply main and the proposed run of pipe on the site by the utility company
5. A preferred location of the meter and/or regulator assembly, and any work required by the owner to allow the assembly to be installed (such as a meter pit or slab on grade)
6. Types of service available and the cost of each

In order for the utility company to provide this data, they require that the following information to be provided:

1. The total connected load. The utility will use their own diversity factor to calculate the size of the service line. If the design engineer is responsible for the installation, this is not required since the diversity factor for the facility shall be used. This shall include pilot light requirements, if any.
2. Minimum and maximum pressure requirements for the most demanding device.
3. Site plan indicating the location of the proposed building on the site, desired point of entry (if known), and the specific area of the building where the proposed NG service will enter the building.
4. Preferred location of the meter/regulator assembly.
5. Firm or dual fuel requirements.
6. Expected date of the start of construction.

MAJOR NATURAL GAS SYSTEM COMPONENTS

Gas Line Filters

Filters for natural and LP gas may be required on the site service to protect the regulator and meter from injury or particulate clogging and damage to the equipment inside the building. They should be considered when:

1. Line scale, dirt, or rust is known to be present
2. Dirty gas is obtained from a transmission company
3. ‘‘Wet’’ gas is known to be present, such as after large regulators

The filter consists of a housing and a cartage filter element. Selection of the housing is based on the highest flow rate and pressure expected and the size of the proposed building service. A filter rating of 10 microns is suggested as a starting point, with actual operating experience being the final criterion. The size of the filter is based on the flow rate and velocity across the filter.

Gas Meters

Gas meters are an integral part of a service assembly that may consist of filters, valves, regulators, and relief valves. The complete assembly is usually supplied and installed by the utility company. For the rare instances where this is not the case, gas meters are selected using the local utility company standards, with the size and arrangement of the entire meter assembly based on flow rate and pressure. Because constant pressure is necessary for accurate metering, the regulator is installed upstream of the meter.

Pressure Regulators

Gas pressure regulators are pressure-reducing devices used to reduce a variable high inlet pressure to a constant lower outlet pressure. Two types of regulators are available; *direct-acting* and *pilot-operated.* The pilot-operated valves are more accurate. It is common practice to oversize the capacity of a regulator by about 15 percent to provide a safety margin for accurate regulation.

There are several categories of regulators, with the end-use determining the nomenclature. The first is the *line regulator,* which is used to reduce high pressure, often in a range of between 25 and 50 psig (170 and 345 kPa), in utility company mains to a lower pressure used for the building service. An *intermediate regulator* is used to reduce a pressure in the range of 3 to 5 psig (21 to 34.5 kPa) to a lower pressure required to supply terminal equipment such as a boiler gas train. The third type is an *appliance regulator,* used at the individual piece of equipment.

Regulators may require a gas vent piped to a safe location, and sized to carry the quantity of gas that will be discharged. This is to protect the system from overpressure in the event of a malfunction or failure to fully lock up (close). Each individual regulator vent must be separate. Common vent lines are not permitted.

The utility company may require that regulators be of the ‘‘lock-up’’ type. This feature will completely shut down a regulator when the pressure rises above a predetermined set point.

SITE DISTRIBUTION

The building service on the site starts at the property line of the customer and usually ends inside of a building, above grade (or the concrete meter pad) or at the valve prior to the customer connection after the meter assembly. It is common practice for the utility company to install the line, including the meter assembly.

SITE BUILDING SERVICE-SIZING PROCEDURE

The size of the service main is calculated using the maximum line pressure in the gas main, selected pressure drop, and the maximum probable flow rate of NG.

TABLE C17.4 Sizing NG Pipe with Initial Pressure of 20 psig and 2 psig Pressure Drop

Length ft	Nominal actual ID	0.50 0.622	0.75 0.824	1 1.049	1.25 1.380	1.5 1.610	2 2.067	2.5 2.469	3 3.068	3.5 3.548	4 4.026	5 5.047	6 6.065
		Capacity of horizontal gas piping (cfh) — Nominal pipe size and actual inside diameter (ID), in. of Sch. 40 pipe											
10		2,723	5,765	10,975	22,804	34,398	66,973	107,577	191,989	282,890	396,270	724,020	1,181,799
20		1,926	4,076	7,760	16,125	24,323	47,357	76,068	135,757	200,034	280,205	511,959	838,658
25		1,722	3,646	6,941	14,422	21,755	42,358	68,037	121,424	178,915	250,623	457,910	747,435
30		1,572	3,328	6,336	13,166	19,860	38,667	62,109	110,845	163,327	228,787	418,013	682,312
35		1,456	3,082	5,866	12,189	18,386	35,799	57,502	102,622	151,211	211,815	387,005	631,698
40		1,362	2,883	5,487	11,402	17,199	33,487	53,788	95,994	141,445	198,135	362,010	590,900
45		1,284	2,718	5,174	10,750	16,215	31,572	50,712	90,504	133,356	186,804	341,306	557,105
50		1,218	2,578	4,908	10,198	15,383	29,951	48,110	85,860	126,512	177,217	323,791	528,517
60		1,112	2,354	4,480	9,310	14,043	27,342	43,918	78,379	115,489	161,777	295,580	482,467
70		1,029	2,179	4,148	8,619	13,001	25,314	40,660	72,565	106,922	149,776	273,654	446,678
80		963	2,038	3,880	8,062	12,161	23,679	38,034	67,878	100,017	140,103	255,980	417,829
90		908	1,922	3,658	7,601	11,466	22,324	35,859	63,996	94,297	132,090	241,340	393,933
100		861	1,823	3,471	7,211	10,878	21,179	34,019	60,712	89,458	125,312	228,955	373,718
125		770	1,631	3,104	6,450	9,729	18,943	30,427	54,303	80,013	112,082	204,784	334,263
150		703	1,489	2,834	5,888	8,881	1,292	27,776	49,571	73,042	102,317	186,941	305,139
200		609	1,289	2,454	5,099	7,692	14,976	24,055	42,930	63,256	88,609	161,896	264,258
300		497	1,053	2,004	4,163	6,280	12,228	19,641	35,052	51,648	72,349	132,187	215,766
400		431	912	1,735	3,606	5,439	10,589	17,009	30,356	44,729	62,656	114,478	186,859
500		385	815	152	3,225	4,865	9,471	15,214	27,151	40,007	56,041	102,392	167,132
1,000		272	577	1,097	2,280	3,440	6,697	10,758	19,199	28,289	39,627	72,402	118,180
1,500		222	471	896	1,862	2,809	5,468	8,784	15,676	23,098	32,355	59,116	96,493
2,000		193	408	776	1,612	2,432	4,736	7,607	13,576	20,003	28,021	51,196	83,566

TABLE C17.4M (metric) Sizing NG Pipe with Initial Pressure of 138 kPa and 15 kPa Pressure Drop

Length m	Capacity of horizontal gas piping (l/s)											
	Pipe size*, DN											
	15	20	25	32	40	50	65	80	90	100	125	150
3	22	46	88	182	275	536	861	1,536	2,263	3,170	5,792	9,454
3	15	33	62	129	195	379	609	1,086	1,600	2,242	4,096	6,709
7.5	14	29	56	115	174	339	544	971	1,431	2,005	3,663	5,979
9	13	27	51	105	159	309	497	887	1,307	1,830	3,344	5,458
10.5	12	25	47	98	147	286	460	821	1,210	1,695	3,096	5,054
12	11	23	44	91	138	268	430	768	1,132	1,585	2,869	4,727
13.5	10	22	41	86	130	253	406	724	1,067	1,494	2,730	4,457
15	9.56	21	39	82	123	240	385	687	1,012	1,418	2,590	4,228
18	9	19	36	74	112	219	351	627	924	1,294	2,365	3,860
21	8.62	17	33	69	104	203	325	581	855	1,198	2,189	3,573
24	8	16	31	64	97	189	304	543	800	1,121	2,048	3,343
27	7.61	15	29	61	92	179	287	512	754	1,057	1,931	3,151
30	7	14	28	58	87	169	272	486	716	1,002	1,832	2,990
37.5	6.52	13	25	52	78	152	243	434	640	897	1,638	2,674
45	6	12	23	47	71	140	222	397	584	819	1,496	2,441
60	5	10	20	41	62	120	192	343	506	709	1,295	2,114
90	4	9	16	33	50	98	157	280	413	579	1,057	1,726
120	3.51	8	14	29	44	85	136	243	358	501	916	1,495
150	3	7	12	26	39	76	122	217	320	448	819	1,337
300	2.82	5	9	18	28	54	86	154	226	317	579	945
450	2.56	4	7	15	22	44	70	125	185	259	473	772
600	2.31	3	6	13	19	38	61	109	160	224	410	669

* For definition of DN, refer to Chap. A1.

The line size is determined by using tables prepared for the maximum line pressure. The pressure drop selected is at the discretion of the design professional, but it is generally kept to approximately 10 percent of the available pressure in psig.

Separate tables giving IP and SI units for the pressures usually encountered in site mains are provided. Tables C17.4 and C17.4M (metric) are for 20 psig (138 kPa), and Tables C17.5 (C17.5M) and C17.5M (metric) are for 50 psig (345 kPa). The pressure drop is 10 percent of the pressure available. The use of these tables is described for sizing the building interior piping.

TABLE C17.5 Sizing NG Pipe with Initial Pressure of 50 psig and 5 psig Pressure Drop

Length ft	Capacity of horizontal gas piping (cfh)												
	Nominal pipe size and actual inside diameter (ID), in. of Sch. 40 pipe												
	Nominal actual ID	0.5 0.622	0.75 0.824	1 1.049	1.25 1.380	1.5 1.610	2 2.067	2.5 2.469	3 3.068	3.5 3,548	4 4.026	5 5.047	6 6.065
10		5,850	12,384	23,575	48,984	73,889	143,864	231,083	412,407	607,670	851,220	1,555,251	2,538,598
20		4,137	8,757	16,670	34,637	52,248	101,727	163,400	291,616	429,688	601,903	1,099,729	1,795,060
25		3,700	7,832	14,910	30,980	46,732	90,988	146,150	260,829	384,324	538,359	983,627	1,605,550
30		3,377	7,150	13,611	28,281	42,660	83,060	133,416	238,103	350,839	491,452	897,925	1,465,660
35		3,127	6,619	12,601	26,183	39,495	76,899	123,519	220,441	324,813	454,996	831,317	1,356,938
40		2,925	6,192	11,787	24,492	36,945	71,932	115,541	206,203	303,835	425,610	777,626	1,269,299
45		2,758	5,838	11,113	23,091	34,832	67,818	108,934	194,411	286,459	401,269	733,152	1,196,706
50		2,616	5,538	10,543	21,906	33,044	64,338	103,343	184,434	271,758	380,677	695,529	1,135,295
60		2,388	5,056	9,624	19,998	30,165	58,732	94,339	168,364	248,080	347,509	634,929	1,036,378
70		2,211	4,681	8,910	18,514	27,927	54,376	87,341	155,875	229,678	321,731	587,830	959,500
80		2,068	4,378	8,335	17,319	26,124	50,864	81,700	145,808	214,844	300,952	549,864	897,530
90		1,950	4,128	7,858	16,328	24,630	47,955	77,028	137,469	202,557	283,740	518,417	846,199
100		1,850	3,916	7,456	15,490	23,366	45,494	73,075	130,415	192,162	269,179	491,814	802,775
125		1,655	3,503	6,668	13,855	20,899	40,691	65,360	116,646	171,875	240,761	439,891	718,024
150		1,510	3,197	6,087	12,648	19,078	37,146	59,665	106,483	156,900	219,784	401,564	655,463
200		1,308	2,769	5,271	10,953	16,522	32,169	51,672	92,217	135,879	190,339	347,765	567,648
300		1,068	2,261	4,304	8,943	13,490	26,266	42,190	75,295	110,945	155,411	283,949	463,482
400		925	1,958	3,727	7,745	11,683	22,747	36,537	65,207	96,081	134,590	245,907	401,388
500		827	1,751	3,334	6,927	10,450	20,345	32,680	58,323	85,938	120,381	219,946	359,012
1,000		585	1,238	2,357	41,898	7,389	14,386	23,108	41,241	60,767	85,122	155,525	253,860
1,500		478	11,011	1,925	4,000	6,033	11,746	18,868	33,673	49,616	69,502	126,986	207,276
2,000		414	876	1,667	3,464	5,225	10,173	16,340	29,162	42,969	60,190	109,973	179,506

TABLE C17.5M (metric) Sizing NG Pipe with Initial Pressure of 345 kPa and 35 kPa Pressure Drop

Length m	Capacity of horizontal gas piping (l/s) — Pipe size*, DN 15	20	25	32	40	50	65	80	90	100	125	150
3	47	99	189	392	591	1,151	1,849	3,299	4,861	6,810	12,442	20,309
6	33	70	133	277	418	814	1,307	2,333	3,438	4,815	8,798	14,360
7.5	30	63	119	248	347	728	1,169	2,087	3,075	4,307	7,869	12,884
9	27	57	109	226	341	664	1,067	1,905	2,807	3,923	7,183	11,725
10.5	25	53	101	209	316	615	988	1,764	2,599	3,640	6,651	10,856
12	23	50	94	196	296	575	924	1,650	2,431	3,405	6,221	10,154
13.5	22	47	89	185	279	543	871	1,555	2,292	3,210	5,865	9,574
15	21	44	84	175	264	515	827	1,475	2,174	3,045	5,564	9,082
18	19	40	77	160	241	470	755	1,347	1,985	2,780	5,079	8,291
21	18	37	71	148	223	435	699	1,247	1,837	2,574	4,703	7,676
24	17	35	67	139	209	407	654	1,166	1,719	2,408	4,399	7,180
27	16	33	63	131	197	384	616	1,100	1,620	2,270	4,147	6,770
30	15	31	60	124	187	364	585	1,043	1,537	2,153	3,935	6,422
37.5	13	28	53	111	167	326	523	933	1,375	1,926	3,519	5,744
45	12	26	49	101	153	297	477	852	1,256	1,758	3,213	5,244
60	10	22	42	88	132	257	413	738	1,087	1,523	2,782	4,541
90	9	18	34	72	108	210	338	602	888	1,243	2,272	3,708
120	8	16	30	62	93	182	292	522	769	1,077	1,967	3,211
150	7	14	27	55	84	163	261	467	688	963	1,760	2,872
300	5	10	19	42	59	115	185	330	486	681	1,244	2,031
450	4	8	15	32	48	94	151	269	397	556	1,016	1,658
600	3	7	13	28	42	81	131	233	344	482	880	1,436

* For definition of DN, refer to Chap. A1.

BUILDING INTERIOR PIPE-SIZING PROCEDURE

In order to size the piping system, the following information must be calculated or established:

1. Minimum gas pressure available from the utility company after the regulator
2. Allowable friction loss for gas flowing through the piping system
3. Equivalent length of the piping system
4. Maximum probable demand
5. The pipe-sizing method acceptable to local codes

Pressure Available From the Utility Company

The minimum pressure that the utility company will guarantee after the meter assembly must be provided upon request. This is based on the pressure available in the utility supply mains adjacent to the facility under design. If there is a specific requirement for equipment that needs a higher pressure, such as that for a boiler, the utility company must be advised of this requirement and guarantee this pressure in writing. If the higher pressure is not possible, a gas pressure booster will be necessary.

In cases where the utility is not providing the meter, the minimum pressure will be given by the utility company for the main at the tie-in point. It is up to the design professional to determine the pressure required for the building equipment.

Allowable Friction Loss in the Piping System

The minimum guaranteed pressure supplied by the utility company after the meter/regulator assembly could be as low as 4 to 7 in of water column (WC) or 1.0 to 1.7 kPa. This is considered low pressure. Because of this, the friction loss of NG through the piping system must be kept low in order to have sufficient pressure to properly operate the terminal appliance or equipment. A range of between 0.2 to 0.5 in WC (0.5 to 1.2 kPa) are generally accepted values, depending on the actual range of pressure available. When the available pressure is higher than 7 in WC (1.7 kPa), a higher allowable friction loss can be used for economy of pipe sizing if the end-use device pressure requirement allows this.

A pressure loss figure of up to approximately 10 percent of the pressure available is a generally accepted value for distribution main piping with high pressure, depending on the actual pressure in the system. A regulator will then be required at each terminal appliance requiring a lower gas pressure. High-pressure gas distribution may not be practical due to the added cost of regulators and relief vents.

Equivalent Length of Piping

The equivalent length of piping is required to calculate the friction loss in all portions of a piping network. This is a total of the measured length of the longest run plus an additional allowance, in straight run of pipe, for the resistance of valves

TABLE C17.6 Equivalent Lengths for Various Sizes of Valves and Fittings

	Nominal pipe size, NPS (DN)*									
Fitting	¾ (20)	1 (25)	1½ (40)	2 (50)	2½ (65)	3 (80)	4 (100)	5 (125)	6 (150)	8 (200)
	Equivalent lengths, ft (m)									
90° elbow	1.00 (0.3)	2.00 (0.61)	2.50 (0.76)	3.00 (0.91)	4.00 (1.22)	5.50 (1.68)	6.50 (1.98)	9.00 (2.74)	12.0 (3.66)	15.0 (4.57)
tee (run)	0.50 (0.15)	0.75 (0.23)	1.00 (0.3)	1.50 (0.46)	2.00 (0.61)	3.00 (0.91)	3.50 (1.07)	4.50 (1.37)	6.00 (1.83)	7.00 (2.13)
tee (branch)	2.50 (0.76)	3.50 (1.07)	4.50 (1.37)	5.00 (1.52)	6.00 (1.83)	11.0 (3.35)	13.0 (3.96)	18.0 (5.49)	24.0 (7.32)	30.0 (9.14)
gas cock (approx.)	4.00 (1.22)	5.00 (1.52)	7.50 (2.29)	9.00 (2.74)	12.0 (3.66)	17.0 (5.18)	20.0 (6.1)	28.0 (8.53)	37.0 (11.28)	46.0 (14.02)

* For definition of NPS and DN, refer to Chap. A1.

The pressure drop through valves should be taken from manufacturers' published data rather than using the equivalent lengths, since the various patterns of gas cocks can vary greatly.

and fittings to flow. It is common practice not to use the vertical length of piping when calculating the total run for NG systems. Since NG is lighter than air, it expands at the rate of 0.1 in WC (0.25 kPa) for every 15 feet (5 m) of elevation as the gas rises. The additional pressure created as the gas rises approximates that lost to friction inside the pipe.

LNG is heavier than air, therefore the entire length of run is used in calculating the pressure loss.

Refer to Table C17.6 for equivalent lengths of fittings and valves for the flow of gas in a pipeline.

Maximum Probable Demand

For some types of buildings, such as multiple dwellings and laboratories, the total connected load is not used to size the piping system since not all of the connected

TABLE C17.7 Approximate Gas Demand for Common Appliances

Appliance	Input-Btu/h (mJ/h)
Commercial kitchen equipment:	
Small broiler	30,000 (31.7)
Large broiler	60,000 (63.3)
Combination broiler and roaster	66,000 (69.6)
Coffee maker, 3 burner	18,000 (19)
Coffee maker, 4 burner	24,000 (25.3)
Deep fat fryer, 45 pounds (20.4 kg) of fat	50,000 (52.8)
Deep fat fryer, 75 pounds (34.1 kg) of fat	75,000 (79.1)
Doughnut fryer, 200 pounds (90.8 kg) of fat	72,000 (76)
2 deck baking and roasting oven	100,000 (105.5)
3 deck baking oven	96,000 (101.3)
Revolving oven, 4 or 5 trays	210,000 (221.6)
Range with hot top and oven	90,000 (95)
Range with hot top	45,000 (47.5)
Range with fry top and oven	100,000 (105.5)
Range with fry top	50,000 (52.8)
Coffee urn, single, 5 gal (18.9 l)	28,000 (29.5)
Coffee urn, twin, 10 gal (37.9 l)	56,000 (59.1)
Coffee urn, twin, 15 gal (56.8 l)	84,000 (88.6)
Stackable convection oven, per section of oven	60,000 (63.3)
Residential equipment	
Clothes dryer	35,000 (36.9)
Range	65,000 (68.6)
Stove top burners	40,000 (42.2)
Oven	25,000 (26.4)
30 gal (113.6 l) water heater	30,000 (31.7)
40 to 50 gal (151.4 to 189.3 l) water heater	50,000 (52.8)
Log lighter	25,000 (26.4)
Barbecue	50,000 (52.8)
Miscellaneous equipment	50,000 (52.8)
Commercial log lighter	50,000 (52.8)
Bunsen burner	5,000 (5.3)
Gas engine, per horsepower (745.7 W)	10,000 (10.6)
Steam boiler, per horsepower (745.7 W)	50,000 (52.8)

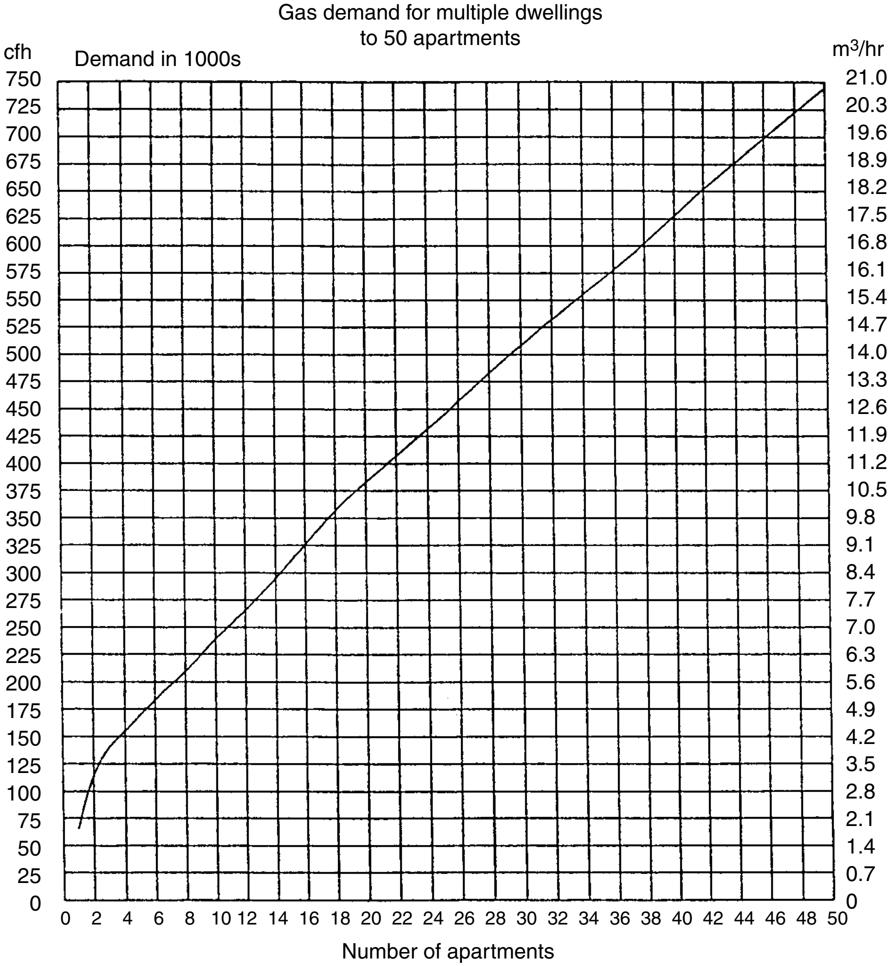


FIGURE C17.1 Gas demand for multiple dwellings (to 50 apartments).

devices will be used at the same time. For design purposes, a diversity factor shall be used to reduce the total connected load. The maximum probable demand is calculated by multiplying the total connected load by the diversity factor.

This calculation first requires the listing of every device using gas in the building and the demand in Btu per hour (Btu/h) or millijoules per hour (mJ/h) for each. The manufacturer of each device should be consulted to find its actual input gas consumption. Average gas demand values for typical devices are listed in Table C17.7.

For multiple dwellings, a direct reading of the quantity of gas used for cooking based on the number of apartments is presented in Fig. C17.1 for buildings up to 50 apartments and Fig. C17.2 for buildings with more than 50 apartments. A diversity factor has been used to create the chart. For the size of individual risers, refer to

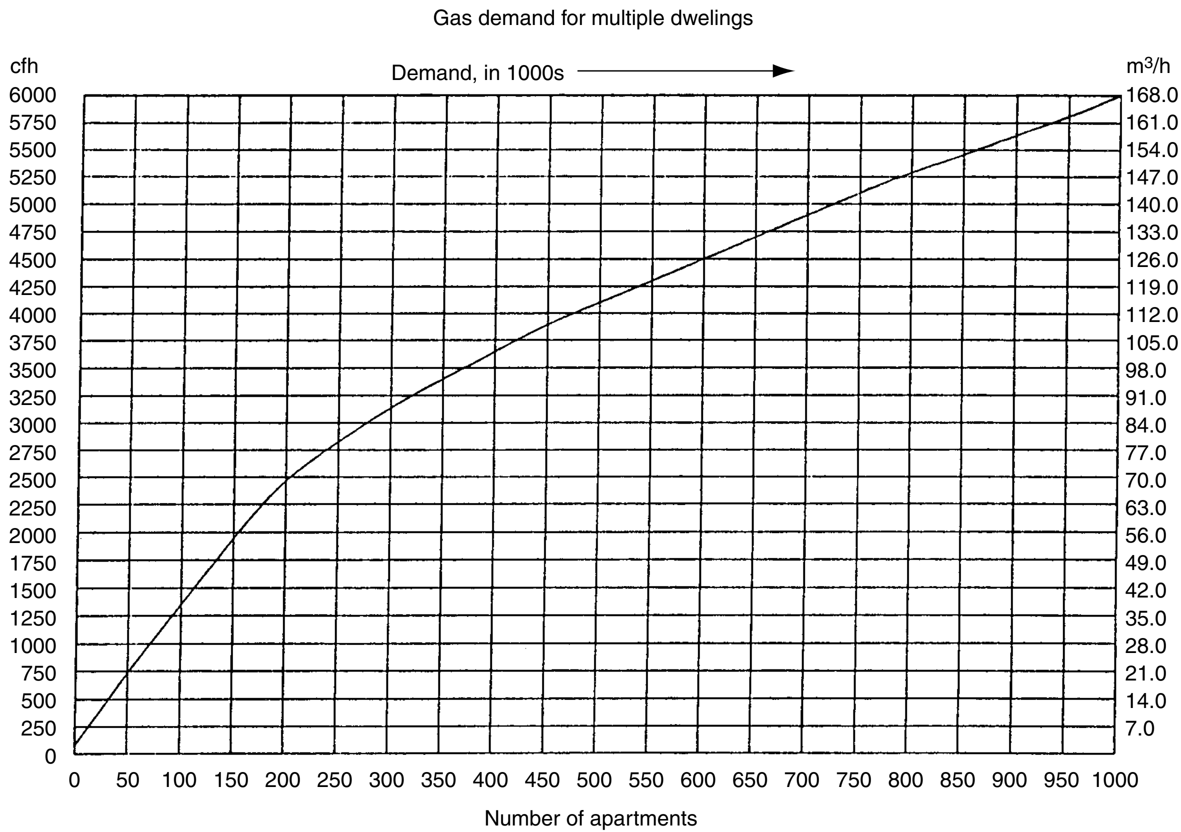


FIGURE C17.2 Gas demand for multiple dwellings.

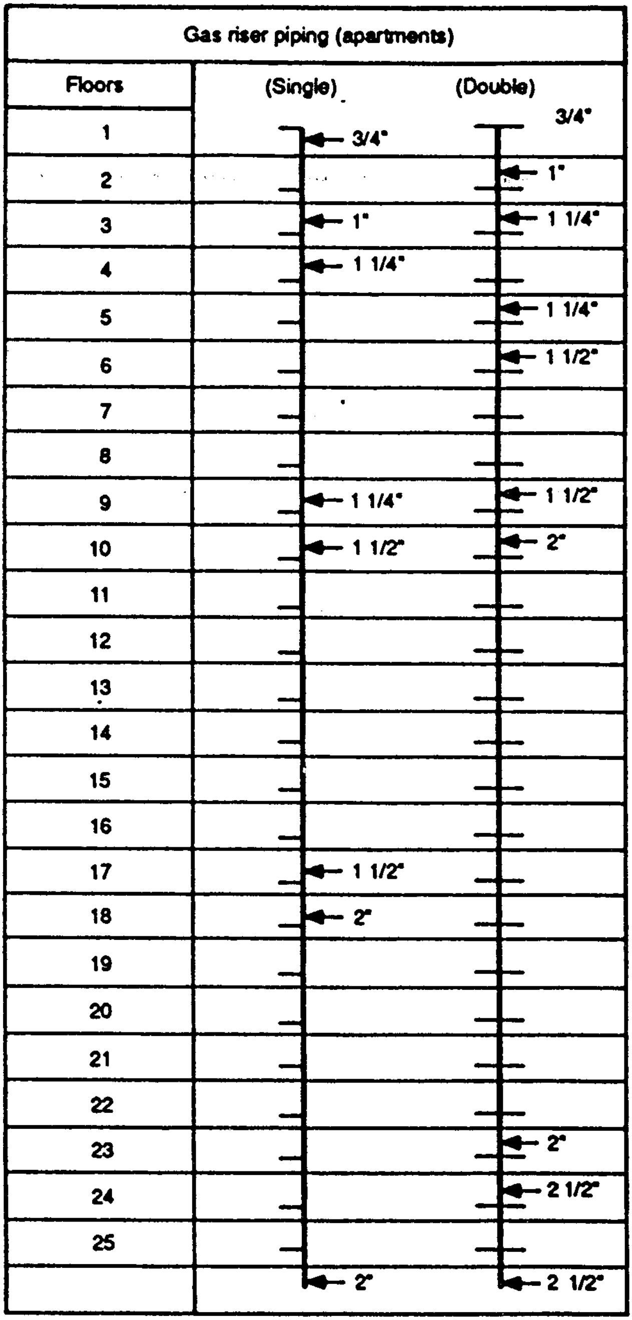


FIGURE C17.3 Gas riser piping (apartments).

TABLE C17.8 Laboratory Diversity Factors

No. of outlets	Average % use	Max.
1–5	100	
6–10	75	90
11–20	60	75
21–70	40	60
71–150	30	50
Over	20	40

Fig. C17.3 for a direct reading of the riser pipe size by floor. For laboratories, refer to Table C17.8 for diversity factors. Where laboratories are part of a school, use no diversity for entire rooms, and consult with the school authorities to find the total number of rooms that might be in use at once. If there is no conclusive answer, use no diversity.

For industrial or process installations, and for major gas-using equipment such as boilers, unit space heaters, and water heaters in all building types, a diversity factor is generally not used because it is possible for all connected equipment to be in use at the same time.

NG Pipe-Sizing Methods

The most conservative method for sizing NG piping systems is by the use of tables, such as those prepared by various code authorities, the American Gas Association, and ones appearing in App. C of the National Fuel Gas code, NFPA 54. Other methods using proprietary tables and calculators are available. The calculators are considered more accurate than the prepared tables.

Two tables, each given in IP and SI units, are provided to allow sizing for a majority of systems. Tables C17.9 and C17.9M (metric) are for low pressure and Tables C17.10 and C17.10M (metric) are for higher pressures. The information in the low-pressure table (for 1 psi [6.9 kPa] or less) has been calculated from the Spitglass formula:

$$Q = 3550K\sqrt{\frac{H}{L}} \tag{C17.1}$$

Information in the tables for pressures greater than 1 psi (6.9 kPa), including those used for site mains, has been calculated by the Weymouth formula:

$$Q = 3550K\sqrt{\frac{PA}{SL}} \tag{C17.2}$$

The constant for any given pipe size can be calculated from the following formula:

$$K = [D^5/[1 + (3.6/D) + (0.03)(D)\ ]]^{1/2} \tag{C17.3}$$

where Q = Quantity of gas at 60°F (15.6°C)
H = Pressure drop, in WC (mm WC)

TABLE C17.9 Sizing of NG Pipe with an Initial Pressure of Less Than 1 psig and Pressure Drop of 0.5 in WC

Lenth ft	Capacity of horizontal gas piping (cfh) — Nominal pipe size and actual inside diameter (ID) of Sch. 40 pipe: Nominal actual ID	0.5 0.622	0.75 0.824	1 1.049	1.25 1.380	1.5 1.610	2 2.067	2.5 2.469	3 3.068	3.5 3.548	4 4.026	5 5.047	6 6.065
10		120	272	547	1,200	1,860	3,759	6,169	11,225	16,685	23,479	42,945	69,671
20		85	192	387	849	1,315	2,658	4,362	7,938	11,798	16,602	30,367	49,265
25		76	172	346	759	1,176	2,378	3,901	7,100	10,552	14,850	27,161	44,064
30		69	157	316	693	1,074	2,171	3,562	6,481	9,633	13,556	24,794	40,225
35		64	145	292	641	994	2,010	3,297	6,000	8,918	12,550	22,955	37,241
40		60	136	273	600	930	1,880	3,084	5,613	8,342	11,740	21,473	34,835
45		56	128	258	566	877	1,772	2,908	5,292	7,865	11,068	20,245	32,843
50		54	122	244	537	832	1,681	2,759	5,020	7,462	10,500	19,206	31,158
60		49	111	223	490	759	1,535	2,518	4,583	6,811	9.585	17,532	28,443
70		45	103	207	454	703	1,421	2,332	4,243	6,306	8,874	16,232	26,333
80		42	96	193	424	658	1,329	2,181	3,969	5,899	8,301	15,183	24,632
90		40	91	182	400	620	1,253	2,056	3,742	5,562	7,826	14,315	23,224
100		38	86	173	379	588	1,189	1,951	3,550	5,276	7,425	13,581	22,032
125		34	77	155	339	526	1,063	1,745	3,175	4,719	6,641	12,147	19,706
150		31	70	141	310	480	971	1,593	2,898	4,308	6,062	11,088	17,989
200		27	61	122	268	416	841	1,379	2,510	3,731	5,250	9,603	15,579
300		24	54	109	240	372	752	1,234	2,245	3,337	4,696	8,589	13,934
400		19	43	86	190	294	594	975	1,775	2,638	3,712	6,790	11,016
500		17	38	77	170	263	532	872	1,588	2,360	3,320	6,073	9,853
1,000		12	27	55	120	186	376	617	1,123	1,668	2,348	4,295	6,967
1,500		10	22	45	98	152	307	504	917	1,362	1,917	3,506	5,689
2,000		8	19	39	85	132	266	436	794	1,180	1,660	3,037	4,926

TABLE C17.9M (metric) Sizing of NG Pipe with an Initial Pressure of Less than 6.9 kPa and Pressure Drop of 1.2 kPa

Length m	Q = Capacity of horizontal gas piping (l/s) — Pipe size, DN: 6	10	15	20	25	32	40	50	65	80	90	100	125	150	200	250	300
3	0.20	0.49	0.96	2.15	4.38	9.60	15	30	49	90	133	188	344	557	1135	2022	3134
6	0.13	0.34	0.67	1.53	2.06	6.79	11	21	35	64	94	133	243	394	802	1430	2216
7.5	0.13	0.30	0.60	1.36	1.46	6.07	9	19	31	57	84	119	217	353	718	1279	1982
9	0.12	0.29	0.55	1.24	1.30	5.54	9	17	28	52	77	108	198	322	655	1168	1809
10.5	0.10	0.25	0.50	1.14	1.19	5.13	8	16	26	48	71	100	184	298	606	1081	1675
12	0.10	0.24	0.47	1.08	1.10	4.80	7.5	15	25	45	67	94	172	279	567	1011	1567
13.5	0.10	0.24	0.44	1.01	1.03	4.53	7.2	14	23	42	63	89	162	263	535	953	1477
15	0.08	0.22	0.42	0.97	0.98	4.30	6.6	13	22	40	60	84	154	249	507	904	1401
18	0.08	0.22	0.39	0.87	0.92	3.92	6	12	20	37	54	77	140	228	463	826	1279
21	0.07	0.18	0.35	0.82	0.84	3.36	5.6	11	19	34	50	71	130	211	429	764	1184
24	0.07	0.17	0.34	0.76	0.78	3.39	5.2	11	17	32	47	66	121	197	401	715	1108
27	0.07	0.15	0.32	0.72	0.73	3.20	5	10	16	30	44	63	115	186	378	674	1045
30	0.07	0.15	0.30	0.69	0.69	3.03	4.7	10	15	28	42	59	109	176	359	640	991
37.5	0.05	0.13	0.27	0.60	0.66	2.71	4.2	9	14	25	38	53	97	158	321	572	886
45	0.05	0.13	0.25	0.55	0.58	2.43	3.8	8	13	23	34	48	89	144	293	522	809
60	0.05	0.12	0.22	0.49	0.54	2.14	3.3	7	11	20	30	42	77	125	254	452	701
90	0.03	0.10	0.18	0.42	0.46	1.92	3	6	10	18	27	38	69	111	227	404	627
120	0.03	0.08	0.15	0.34	0.41	1.52	2.3	5	8	14	21	30	54	88	179	320	495
150	0.03	0.07	0.13	0.30	0.33	1.36	2.1	4	7	13	19	27	49	79	160	286	443
300	0.02	0.05	0.10	0.22	0.29	0.96	1.5	3	5	9	13	19	34	56	113	202	313
450	0.02	0.03	0.08	0.17	0.21	0.78	1.2	2	4	7	11	15	28	46	93	165	256
600	0.02	0.03	0.07	0.15	0.17	0.68	1	2	3	6	9	13	24	39	80	143	222

TABLE C17.10 2, 5 & 10 psig Pressure

Inlet pressure	Flows in table are scfh[(1)] of 0.6 sp. gr. natural gas							
Inlet pressure, psig	kPa	DN	Pipe size, inches	Pressure drop per 100 equivalent feet of pipe as a percentage of inlet pressure 2%	4%	6%	8%	10%
2	13.8			340	480	590	680	760
5	34.5			590	840	1030	1180	1320
10	69	25	1	930	1320	1610	1850	2070
2	13.8			710	1010	1230	1420	1590
5	34.5			1230	1740	2130	2450	2740
10	69	32	1-¼	1950	2760	3370	3880	4330
2	13.8			1080	1530	1870	2160	2410
5	34.5			1860	2630	3220	3710	4140
10	69	40	1-½	2940	4160	5080	5850	6530
2	13.8			2100	2980	3640	4200	4700
5	34.5			3630	5120	6270	7230	8070
10	69	50	2	5740	8090	9890	11,400	12,720
2	13.8			3390	4810	5880	6780	7580
5	34.5			5850	8260	10,100	11,650	13,010
10	69	65	2-½	9240	13,040	15,940	18,370	20,500
2	13.8			6060	8590	10,500	12,120	13,540
5	34.5			10,450	14,760	18,050	20,820	23,240
10	69	80	3	16,510	23,290	28,480	32,810	36,610
2	13.8			12,480	17,690	21,620	24,960	27,890
5	34.5			21,520	30,400	37,180	42,890	47,880
10	69	100	4	34,000	47,980	58,650	67,580	75,410
2	13.8			37,250	52,800	64,560	74,510	83,270
5	34.5			64,240	90,760	111,010	128,040	142,950
10	69	150	6	101,520	143,260	175,120	201,780	225,150

Note 1 scfh = 0.008 l/s.

S = Specific gravity of the gas
L = Equivalent length of pipe, ft (m)
P = Pressure drop, psi (kPa)
A = Average pressure in the pipe, psi (kPa)
K = constant for any given pipe size
D = Inside diameter of the pipe, in (mm)

The proper pressure chart is selected by first determining initial system pressure and then establishing the acceptable friction loss. Next, calculate the equivalent run of pipe from the outlet of the meter or regulator (or point of connection) to the farthest point of use. *This is the only distance used.* Using a straight-edge as a guide, find the pipe size at the intersection of the pipe length row with a cfh (l/s) column that equals or exceeds the calculated cfh (l/s) figure at each design point. Branches are sized using the same distance column but with the cfh (l/s) figure from the branch to connection with the main. The straight-edge does not move. Start the sizing procedure from the farthest point in the system.

The high-pressure table is used by first deciding on the total pressure loss acceptable for the entire system. Entering with the inlet pressure and the total system pressure drop, find the lowest cfh (l/s) figure that equals or exceeds the calculated cfh (l/s). Read the size at the head of the correct column. Interpolate to find the actual gas flow when using intermediate pressure and friction loss figures.

TABLE C17.11 Specific Gravity Multipliers

Specific gravity	Flow rate capacity multiplier	Specific gravity	Flow rate capacity multiplier
0.35	1.310	1.00	0.775
0.40	1.230	1.10	0.740
0.45	1.160	1.20	0.707
0.50	1.100	1.30	0.680
0.55	1.040	1.40	0.655
0.60	1.000	1.50	0.633
0.65	0.962	1.60	0.612
0.70	0.926	1.70	0.594
0.75	0.895	1.80	0.577
0.80	0.867	1.90	0.565
0.85	0.841	2.00	0.547
0.90	0.817	2.10	0.535

Fuel gases with different heating values from that of NG generally have a specific gravity proportional to NG. If a gas fuel with a different specific gravity is being used, the multipliers found in Table C17.11 can be used to adjust the flow rate found in the NG sizing tables.

Example C17.1: Design Example

Refer to Fig. C17.4 for a schematic diagram of a piping network.

1. Determine the lowest initial system pressure after the meter assembly. For this example, a pressure of 6 in WC (1.2 kPa) has been obtained from the utility company.
2. Select the allowable pressure drop. Since the pressure is low, a small pressure drop of 0.3 in WC (0.07 kPa) is selected.
3. Calculate the diversity factor to be used. For this example, no diversity will be used.
4. Calculate the equivalent length of piping. With a measured length of 400 ft (120 m), an additional length of 200 ft (63 m) is added for fittings, giving an equivalent length of 600 ft (183 m).

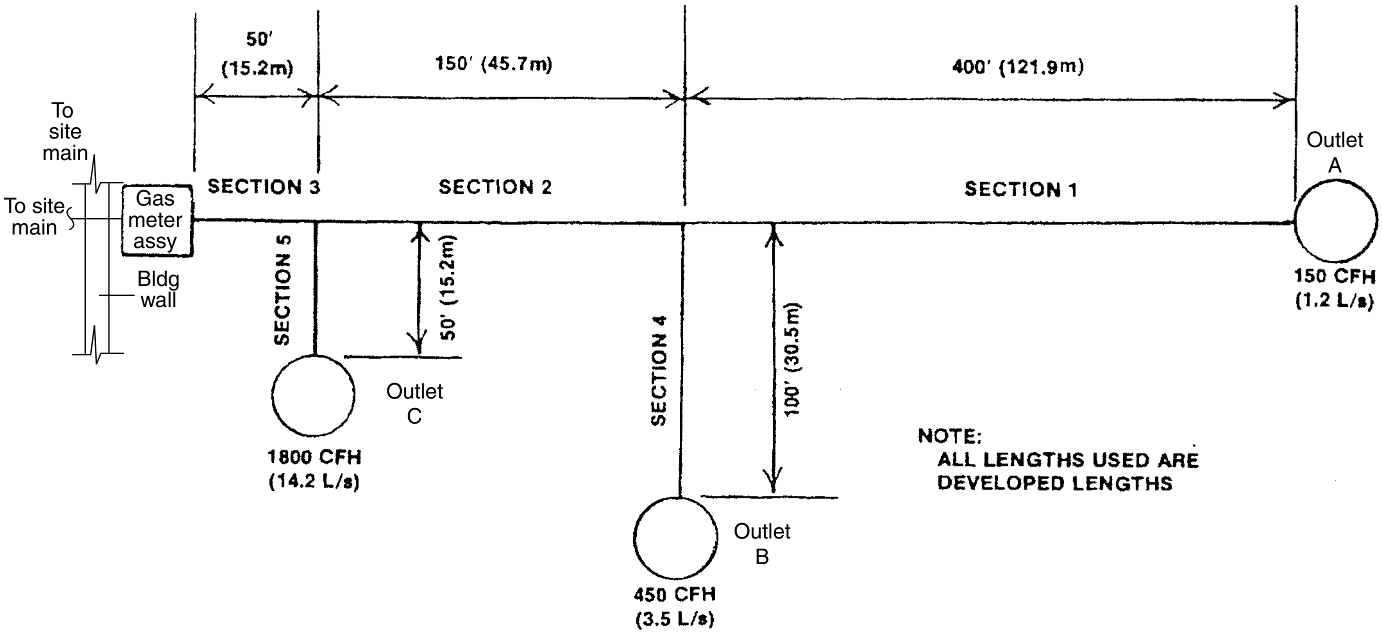


FIGURE C17.4 Piping network sizing example.

5. Calculate the flow rate at all of the design points (sections) with devices or outlets. The use is as follows:

   Outlet A = 150 cfh (1.2 l/s)

   Outlet B = 450 cfh (3.5 l/s)

   Outlet C = 1800 cfh (14.2 l/s)

   2400 cfh (68.9 l/s)

6. Enter Table C17.9 (C17.9M) (Low-Pressure Gas-Sizing Table) with the equivalent length of run and the cfh at each design point. If the distances are not exactly those that appear on the chart, use the shorter length closest to that calculated and interpolate the cfh figure.
7. The method of using the tables has been previously discussed in sizing methods. Using the 600 ft length and starting from the most remote point, find 3320 (the next-larger number than 2400 cfh design figure). Read 4 in size at the head of that column. Continue back toward the meter, sizing each section in turn. Each of the branches is sized using the cfh figure for that length of branch piping without moving the straight-edge.

PIPE AND SYSTEM MATERIALS

All of the piping materials used throughout the system must be listed in NFPA 54 and other applicable codes. Often, the Plumbing Code will have provisions that apply to gas piping systems.

The pressure rating of the various metallic components must exceed the working pressure of the system. Pipe and fittings are usually designated as "class" with a pressure-temperature rating. Class 150 means that Class 150 carbon steel flanges are rated for a working pressure of 285 psi at 100°F (1966.5 kPa at 38°C). The working pressure rating decreases with the increasing service temperature. Another designation, used mainly with valves, is a *water oil and gas* (WOG) rating. 150 psi WOG means a working pressure of 150 psi (1034.5 kPa) at ambient temperature. Refer to Chap. A10.

For plastic pipe, a standard dimensional ratio (SDR) has a pressure rating for that particular pipe material and jointing method. For more details refer to Chap. D1.

Site Underground Piping

The most often used piping material underground on the site is high-density polyethylene (HDPE) with heat-fused butt joints. Socket-type joints in large sizes have often been found to develop unacceptable stress in the pipe. The lower the standard dimension ratio (SDR) the higher pressure rating of pipe. Therefore, care must be taken to select the correct SDR pipe. The pipe shall be buried a minimum of 3.0 ft (1 m) belowground and have a corrosion-resistant tracer wire placed in the pipe trench 6 in (150 mm) over the pipe. Another tracing method is to put a warning tape containing metallic material with the words "Natural Gas" on it. This is to allow location by a metal detector and to warn of the gas line immediately below the tape if digging has taken place without trying to locate the pipe beforehand. For larger lines and piping for high pressure the piping material of choice is black steel pipe, ASTM A106 or A53, with welded joints. To prevent corrosion, the pipe exterior is protected with a factory-applied plastic coating or "mill wrapping," or it is field-wrapped.

Interior Piping

Piping above ground shall be metal; therefore a transition fitting from plastic pipe to metallic pipe is required, conforming to ASTM D2517. Refer to Fig. C17.5.

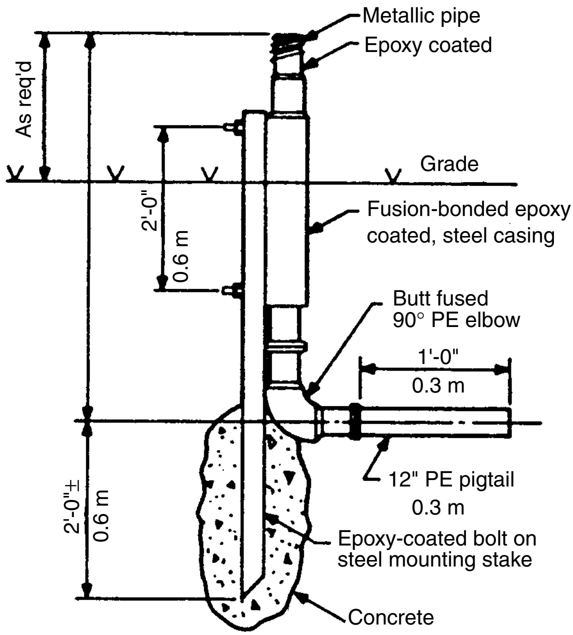


FIGURE C17.5 Typical transition fitting.

Codes do not permit plastic pipe to be run aboveground. For aboveground lines, the piping and jointing methods depend on pipe size and system pressure. For piping up to 3 psig (21 kPa), black steel, ASTM A53 pipe is used with cast-or malleable-iron screwed fittings in sizes NPS 3 (DN 80) and smaller and butt-welded joints NPS 4 (DN 100) and larger. Pipe could be either seamless or welded. Where natural gas is considered "dry gas," type "L" copper pipe is finding widespread use. All piping for pressures over 3 psig (21 kPa) shall be steel with welded joints. Butt- or socket-welding fittings shall conform to ASME B16.9 and B16.11 respectively. See Chaps. A2 and A4. Screwed fittings shall be black malleable iron, class 150 conforming to ASTM A197 and ASME B16.3. Refer to Chap. A4 for additional details.

It is common practice to connect appliances to building piping with a spiral-wound flexible metal hose with threaded ends, commonly called an *appliance connector.* They should be limited to approximately 6 ft (2 m) in length.

Joints for HDPE should be butt-type, heat-fused joints. Socket-type joints have been found to introduce a stiffness in the joint area that is undesirable. Joints for steel pipe shall be screwed for pipe sizes NPS 4 (DN 100) and smaller. Sizes NPS 5 (DN 125) and larger should be welded. Flanged joints should be used only for equipment and valve connections. Dresser couplings, similar to mechanical joints, are another type of joint used for metallic pipe.

Valves

Shutoff valves shall be located in easily accessible locations and near appliances. Valves NPS 4 (DN 100) and larger are usually lubricated plug valves. Valves NPS 3 (DN 80) and smaller are usually nonlubricated plug valves. Small valves used for appliances are plug valves called *gas cocks.*

Check valves are usually swing-disk-type, having a cast iron-body with stainless steel type 316 trim and a soft seat. Sizes NPS 3 and smaller are usually provided with screwed joints. Larger sizes have flanged ends.

In areas that are in active earthquake zones, special valves are available that will close automatically upon vertical or horizontal motion exceeding preset limits.

SYSTEM TESTING AND PURGING

Site Piping

After installation of the pipe is complete, the site system shall be tested, purged of air, and then filled with natural gas. The testing phase shall be done with compressed air at a gauge pressure 50 percent higher than the highest pressure expected in the main. The larger the total volume of the pipe, the longer the test shall last. No loss of pressure shall be allowed. A strip chart arrangement is helpful to determine if any pressure is lost.

As an example, the following is the recommended length of time for a NPS 6 (DN 150) HDPE pipe to be tested:

Length		
Feet	Meters	Test time, hr
1,200	360	10
950	285	8
700	210	6
450	135	4
300	90	3
200	60	2

After successful testing, the line shall be purged of air with dry nitrogen or other inert gas. The reason for this is to prevent a flammable mixture of gas and air when the pipe is filled with natural gas for the first time. Calculate the volume of the piping and introduce an equal volume of nitrogen into the pipe. After the nitrogen purge, natural gas is then introduced until the nitrogen is displaced. It is recommended that the pipe then be left under pressure.

Interior Piping

Test low-pressure gas piping (system pressure of 8 in Hg [27 kPa] or less) with air or fuel gas at 3 psi (21 kPa) for a minimum of one hour. Where system pressure in 9 in WC to 5 psig (2.2 to 34.5 kPa), test with air at 50 psi (345 kPa) for four hours without drop. Where system pressure is greater than 5 psig (34.5 kPa), test with air at 100 psig (690 kPa). Pressure shall be maintained for at least four hours without drop. A strip chart should be considered if a record of the test results is desired.

After the piping distribution system is installed, it must be first blown clear of any debris, then pressure tested to assure a leakproof system. The final step is to purge all lines of air and introduce NG into the system prior to placing it in operation. The pipe terminal releasing gases to the atmosphere during the purging operation shall be located in a safe area and continuously supervised.

LIQUEFIED PETROLEUM GAS (LPG)

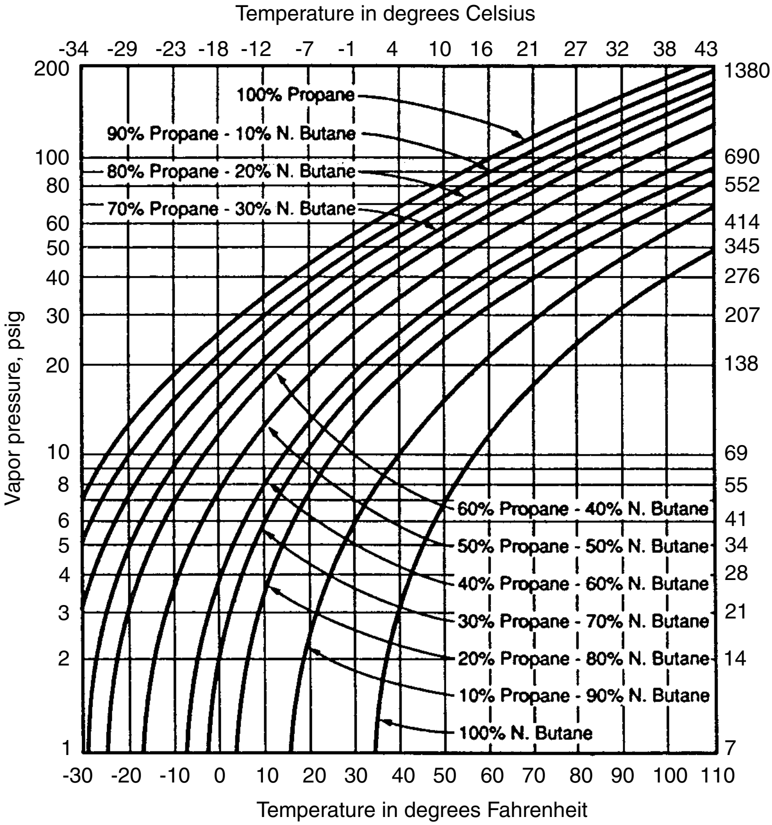
LPG is supplied to facilities from a truck or railroad tank car and is stored in tanks on-site as a liquid. Where usage warrants the installation, permanent tanks are installed on facility property and refilled directly from a tanker truck or railroad car. If the usage requirements are small, nonpermanent propane tanks containing liquid may be installed. The empty tanks are removed and replaced with full tanks.

The liquid must be vaporized to produce a gas. Depending on the actual installation and flow rate, the liquid can be vaporized in the storage tank (using heat gained through the storage tank wall) or by the use of an auxiliary vaporizer. The gas may be used as vaporized or, if it is a substitute supply for natural gas, it may have to be mixed with air to provide a lower heat content suitable for the specific application and equipment.

LPG STORAGE TANKS

Tanks used for the storage of propane are made of steel. They can be installed either above or below grade. Although underground tanks have an advantage of a more constant environment, most tanks are placed above ground because of the lower initial cost. The Environmental Protection Agency in the United States also has requirements. Because of the relatively high pressure developed by the propane vapor, all tanks must be designed in conformance with Sec. VIII of the ASME Boiler and Pressure Vessel Code. The vapor pressure developed in aboveground tanks is based on the ambient outside air temperature, and can be found from Fig. C17.6. For underground tanks, use a figure of 50°F (10°C). Typical capacities of large, standard tanks are shown in Fig. C17.7. The dimensions and capacity of smaller, standard tanks are summarized in Table C17.12. The dimensions vary slightly from manufacturer to manufacturer. For other, nonstandard tanks, refer to Fig. C17.8 for a simplified method for calculating the areas of tanks with various other configurations.

Although it is common practice to classify containers as either portable or stationary, there are too many exceptions to make these classifications practical. Containers and storage tanks in the United States are referred to as either Depart-



Courtesy: Fisher Regulator

FIGURE C17.6 Vapor pressure produced from different mixtures of propane and butane.

ment of Transportation (DOT) cylinders (generally portable) or ASME tanks (generally stationary). In the following discussions, all capacities referring to *gallons* are *gallons of water,* and all *weights* are of *liquid propane,* unless indicated otherwise.

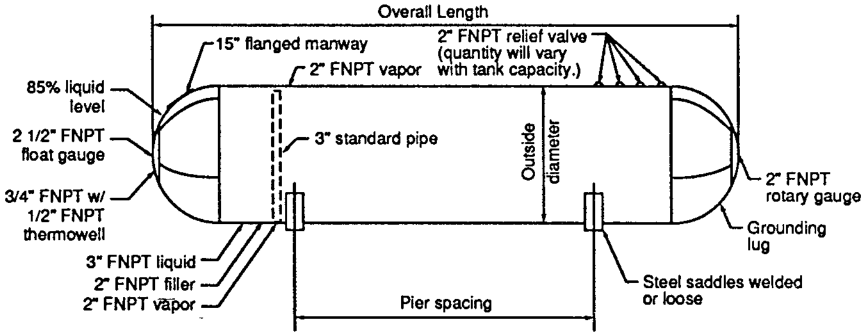
DOT cylinders range in size from 1 to 420 lb (190 kg) capacity. Cylinders built in 1966 or earlier may bear the Interstate Commerce Commission (ICC) designation. ASME tanks range in size from 500 to 60,000 gals (2270 to 272,499 kg) capacity.

The advantages of an underground tank are:

1. The tank is not visible, a plus if aesthetics are a consideration.
2. There is greater vaporization of liquid in the winter due to the constant temperature, which is about 50°F (10°C).

The disadvantages are:

1. The tank may have to be anchored to prevent floating in areas of high water tables.



Dimensions and Capacities of Larger Tanks

Capacity, in gallons	Dia, inches	Length	Pier spacing	Estimated weight, lbs
6,565	84	25' – 10"	8' – 0"	11,260
9,200	84	35' – 4"	17' – 6"	15,920
12,000	84	44' – 10"	27' – 0"	20,035
14,500	84	54' – 4"	36' – 6"	25,230
18,000	109	40' – 11"	21' – 0"	30,502
20,000	109	46' – 11"	27' – 0'	35,300
25,000	109	56' – 5"	36' – 6"	43,100
30,000	109	65' – 11"	46' – 0"	50,900
30,000	121	53' – 3"	32' – 4"	50,000
30,000	121	46' – 9"	24' – 11"	50,100

FIGURE C17.7 Dimensions and capacities of larger tanks.

TABLE C17.12 Dimensions and Surface Areas of Smaller Standard LP-Gas Tanks

		Dimensions		Surface area (sq ft)				
					Wetted surface			
Tank size (gal)	Net propane capacity gal, 60°F	Outside diameter (in)	Over-all length	Total surface sq ft	15% full	25% full	35% full	50% full
120	99	24	5 ft 7 in	35.1	7.0	8.75	14.0	17.5
150	124	24	6 ft 11 in	43.5	8.7	10.8	17.4	21.7
250	207	30	7 ft 5 in	58.3	11.6	14.8	23.3	29.1
325	269	30	9 ft 6 in	74.6	14.8	17.6	29.8	37.3
500	414	37	10 ft 0 in	96.9	19.4	24.2	38.7	48.4
1000	827	41	16 ft 1 in	172.6	34.8	43.1	69.1	86.3

1 gal = 4.546 l.
1 ft = 0.304 m.
1 in = 25.4 mm.
1 sq ft = 0.092 m^2.

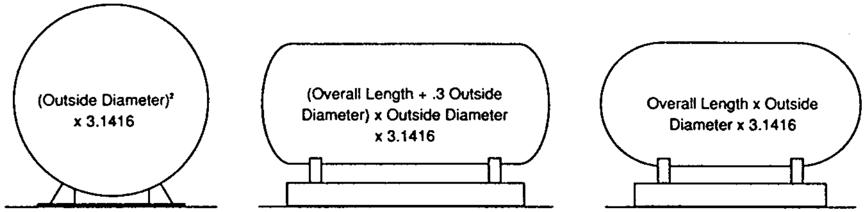


FIGURE C17.8 Area of nonstandard tanks.

2. The initial cost is higher.
3. Inspection and maintenance are more difficult.

If the underground tank is subject to traffic or potential damage, the top should be a minimum of 2 ft below grade. In remote locations, 6 in of cover is considered adequate. A manhole giving access to the valves, gauges, connections, and so forth must be provided for maintenance and inspection.

New tanks must be purged of both air and water prior to being placed in service. A concentration of 6% air is the maximum limit acceptable. Water should removed from the tank by the manufacturer, and the tank should be shipped to the site sealed.

LPG EQUIPMENT ON THE SITE

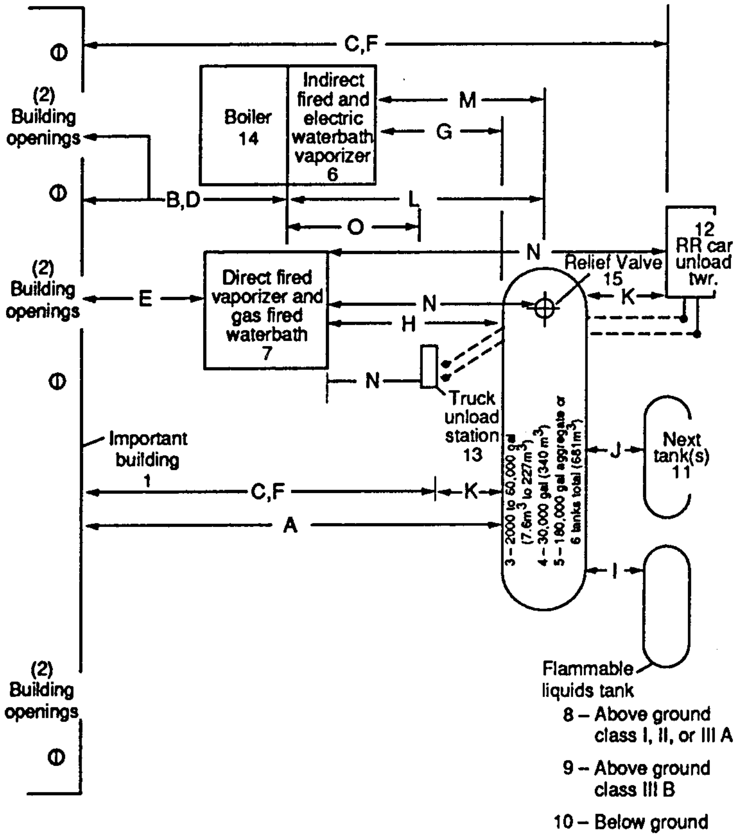
Factors to be considered in locating LPG equipment are:

1. Code-required clearance from other buildings, property line, and any other equipment. These clearances also depend on insurance carrier requirements and client preferences. Factory Mutual requirements, indicated in Fig. C17.9, are considered conservative. Distances in NFPA 54 and those required by other insurance carriers vary, but are not longer.
2. Accessibility for fuel delivery.
3. Avoidance of underground utilities and structures.
4. Avoid placing at low points of a site.
5. Client preferences.

Regulators

The regulator for LPG is different from that used for natural gas service. The purpose of an LPG regulator is to reduce a variable inlet pressure to a constant outlet pressure under variable flow conditions. The following information is required to size a regulator:

1. The minimum significant and maximum flow rate possible
2. Maximum and minimum container pressure



Minimum Recommended Distance			
Dimension	Point to point	Distance, ft	Distance, m
A	1 to 3a	75	23
	4a	150	46
	5b	200	60
	5c	350	105
B	6	20	6
C	12	200	60
	13	50	15
D	2 to 6	20	6
E	7	50	15
F	12	200	60
	13	75	23
G	3,4,5 to 6	5	1.5
H	7	15	4.5
I	8	100	30
	9	50	15
	10	20	6
J	11	75	23
K	12	75	23
	13	50	15
L	14	75	23
M	6 to 15	50	15
N	7 to 12,13,15	75	23
O	13 to 14	75	23

Notes:

a. For single tanks only. Treat multiple tanks as No. 5.
b. For buildings with hydrant protection.
c. For buildings without hydrant protection.
d. 5 ft (1.5 m) for tanks within a group.
e. For tanks smaller than 2000 gal (7.6 m^3), 25 ft (7.6 m).

FIGURE C17.9 Clearance from propane equipment to buildings and other areas.

3. Required outlet pressure desired

4. Manufacturer's rating curves for the regulator

The pressure developed inside the storage tank is produced by the vaporization of product inside the storage tank. This pressure is called the *vapor pressure.* This figure varies, depending on the ambient temperature. Figure C17.6 is a direct-reading chart to determine the vapor pressure for various mixtures of propane and butane that might be provided by suppliers. Outside temperatures can be found by requesting this information from the National Oceanographic and Atmospheric Administration (NOAA).

TABLE C17.13 Regulator Relief Valve Settings

Regulator Delivery Pressure	Relief valve start-to-discharge pressure setting (percent of regulator delivery pressure)	
	Minimum	Maximum
1 psig (6.9 kPa) or less	200%	300%
Above 1 psig (6.9 kPa) but not over 3 psig (20.7 kPa)	140%	200%
Above 3 psig (20.7 kPa)	125%	200%

Regulators are manufactured in single- and double-stage models and are selected using the capacity and rating curves supplied by the manufacturer. If a relief valve is provided as part of the regulator assembly, refer to Table C17.13 for pressure settings.

Pressure-Relief Devices

The purpose of pressure-relief devices is to automatically vent propane vapor to the atmosphere when pressure in the system reaches a predetermined high level. It can be an integral part of a pressure regulator, separately installed on the storage tank, part of vaporizers and mixers, or in the piping system itself.

The relief valve flow capacity is calculated on the basis of a full tank and the resultant vaporization of that volume of propane. For an underground tank, the capacity will be 30% of the aboveground value. Refer to Table C17.14 to determine the required flow of propane based on the square foot (m^2) area of the storage tank. All larger tanks must have a separate relief valve installed directly on the tank. If a single relief valve does not have the required flow capacity, multiple relief valves will be required. A typical tank relief valve is illustrated in Fig. C17.10.

The final pressure setting of the relief valve is nominally 88 percent to 100 percent of the design pressure of the tank, with a permitted error of +10 percent.

Another pressure-relief device within the piping system is the *external bypass valve,* which relieves excessive pressure in an LPG pumping system upon reaching a high-pressure set-point, and returns the discharge back to the storage tank instead of to the atmosphere as is done by a relief valve. All LPG pumps require an external bypass valve.

TABLE C17.14 Relieving Capacity for Relief Valves on Tanks and Vaporizers

Surface area, sq ft	Flow rate, cfm air	Surface area, sq ft	Flow rate, cfm air	Surface area, sq ft	Flow rate, cfm air
20	626	170	3,620	600	10,170
25	751	175	3,700	650	10,860
30	872	180	3,790	700	11,550
35	990	185	3,880	750	12,220
40	1,100	190	3,960	800	12,880
45	1,220	195	4,050	850	13,540
50	1,330	200	4,130	900	14,190
55	1,430	210	4,300	950	14,830
60	1,540	220	4,470	1,000	15,470
65	1,640	230	4,630	1,050	16,100
70	1,750	240	4,800	1,100	16,720
75	1,850	250	4,960	1,150	17,350
80	1,950	260	5,130	1,200	17,960
85	2,050	270	5,290	1,250	18,570
90	2,150	280	5,450	1,300	19,180
95	2,240	290	5,610	1,350	19,780
100	2,340	300	5,760	1,400	20,380
105	2,440	310	5,920	1,450	20,980
110	2,530	320	6,080	1,500	21,570
115	2,630	330	6,230	1,550	22,160
120	2,720	340	6,390	1,600	22,740
125	2,810	350	6,540	1,650	23,320
130	2,900	360	6,690	1,700	23,900
135	2,990	370	6,840	1,750	24,470
140	3,080	380	7,000	1,800	25,050
145	3,170	390	7,150	1,850	25,620
150	3,260	400	7,300	1,900	26,180
155	3,350	450	8,040	1,950	26,750
160	3,440	500	8,760	2,000	27,310
165	3,530	550	9,470		

Note: Buried tanks require only 30 percent of the vent capacity shown.

Minimum required rate of discharge in cubic feet per minute of air at 120 percent of the maximum permitted start-to-discharge pressure for relief valves to be used on containers other than those constructed in accordance with Department of Transportation specifications.

1 sq ft = 0.0929 m^2.

1 cfm = 0.472 l/s.

Courtesy Factory Mutual

Excess Flow Valve

An excess flow valve permits the flow of vapor or liquid in both directions, but shuts off the flow of liquid or vapor in one direction when the flow exceeds a predetermined limit. It is recommended that an excess flow device be placed on all connections to a larger tank except for the safety relief valve and filler connection, which should have an integral one.

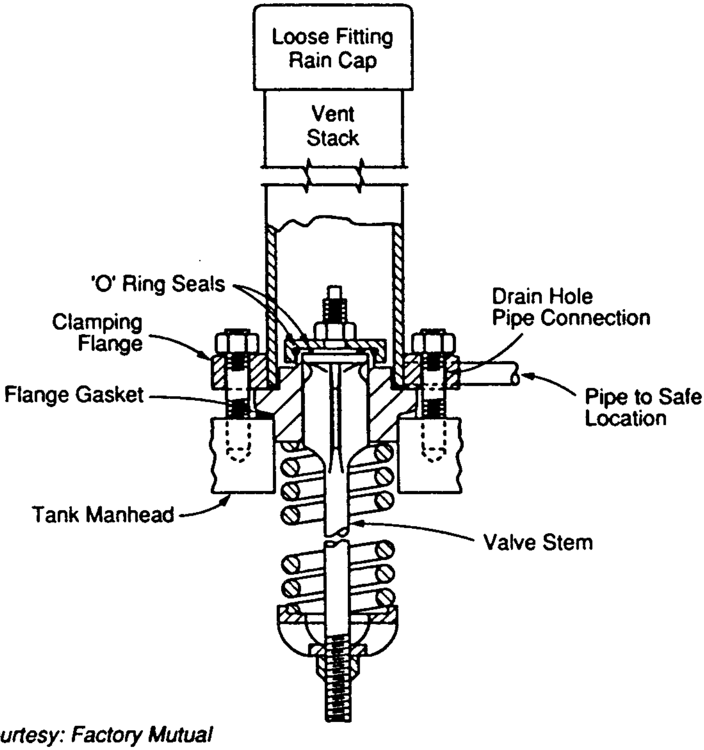


FIGURE C17.10 Tank relief valve.

The valve's capacity is calculated from the largest expected flow and its mounting position (horizontal or vertical). Valves are selected to close at between 150 and 200 percent of maximum expected flow.

Service Line Valves

A service line valve controls the flow of propane from a DOT cylinder. This is a multipurpose valve that could contain a shut-off valve, relief valve, gauge, and filler valve all in one body.

Filler Valves

A filler valve permits the flow of liquid in one direction only, and is used for filling larger tanks with liquid. This valve contains an integral backpressure check valve that will prevent the loss of vapor or liquid from the tank if the fill hose or a fitting ruptures. A preferred location is at the filling connection used by the delivery truck hose.

Vapor-Equalizing Valves

When large tanks are filled, the liquid propane added to the storage tank compresses the vapor in the tank. A vapor-equalizing line is connected between the vapor area of the receiving tank and the vapor area of the delivery truck during propane deliveries to equalize pressure in both containers and to lessen the head requirements of the supply pump. The vapor-equalizing valve is mounted in the tank truck equalizing line hose connection and permits the flow of vapor both ways.

Liquid Level Gauges

When a larger tank is filled on the basis of volume, it is important that a liquid level gauge be installed on the tank to indicate the exact liquid level inside. There are several types available, such as a *slip-tube, fixed-level gauge, magnetic float gauge,* and *rotary* type.

Miscellaneous Equipment

In addition to the devices indicated, it is often desirable to install a liquid temperature gauge and a pressure gauge on a tank to aid in diagnosing any potential problem.

Vaporizer

A vaporizer is a device that converts liquid propane into a vapor in larger quantities outside of the storage tank. It is required when sufficient quantities of propane inside the storage tank cannot be vaporized quickly enough to satisfy the maximum demand.

There are two basic types of vaporizers: *direct fired* and *indirect fired.* The direct fired type uses the propane itself as fuel for the direct flame. The indirect type is available using steam, a glycol/water bath, or the lesser-used electric resistance heaters as a heat source.

Propane Mixers

A mixer, also called a *blender* or *proportioner,* is a device used to combine LPG and air. Experience has shown that a mixed gas content of 1400 Btu/cf with a specific gravity of 1.28 provides the best burning characteristics. Refer to Table C17.15 for properties of various mixtures of propane and air.

Several methods can be used to accomplish mixing, such as a *venturi and a proportional blender.*

The proportional blender is intended for exterior installation. Because the venturi principle is accurate only within a very limited flow range, this type of unit is either on or off. If the demand pressure is higher than 5 psi (34.5 kPa), the use of an air compressor will be required to raise the mixed-gas pressure.

Another device is the *modulating proportional blender.* Suitable only for interior installation, these units are generally used for larger quantities and higher pressures than available from a venturi unit.

TABLE C17.15 Propane/Air Mixtures

Btu per cubic foot of mixture	Percentage of propane by volume	Percentage of air by volume	Percentage of oxygen by volume (orsat)	Specific gravity of the mixture
2550	100.00	0.00	0.000	1.523
2500	98.04	1.96	0.409	1.513
2450	96.08	3.92	0.819	1.502
2400	94.12	5.88	1.288	1.492
2350	92.16	7.84	1.639	1.482
2300	90.19	9.81	2.050	1.472
2250	88.24	11.76	2.458	1.461
2200	86.27	13.73	2.869	1.451
2150	84.31	15.69	3.279	1.441
2100	82.35	17.65	3.688	1.431
2050	80.39	19.61	4.098	1.420
2000	78.43	21.56	4.506	1.410
1950	76.47	23.53	4.918	1.400
1900	74.51	25.49	5.317	1.390
1850	72.55	27.45	5.737	1.379
1800	70.58	29.42	6.149	1.369
1750	68.62	31.38	6.558	1.359
1700	66.67	33.33	6.964	1.349
1650	64.70	35.30	7.378	1.338
1600	62.74	37.26	7.787	1.328
1550	60.78	39.22	8.197	1.318
1500	58.82	41.18	8.606	1.308
1450	56.86	43.14	9.016	1.297
1400	54.90	45.10	9.246	1.287
1350	52.94	47.06	9.835	1.277
1300	50.98	49.02	10.245	1.267
1250	49.02	50.98	10.654	1.256
1200	47.06	52.94	11.064	1.246
1150	45.09	54.91	11.476	1.236
1100	43.13	56.87	11.886	1.226
1050	41.17	58.83	12.295	1.215
1000	39.21	60.79	12.705	1.205
950	37.25	62.75	13.115	1.195
900	35.29	64.71	13.524	1.185
850	33.33	66.67	13.934	1.174
800	31.37	68.63	14.344	1.164
750	29.41	70.59	14.753	1.154
700	27.45	72.55	15.163	1.144
650	25.49	74.51	15.573	1.133
600	23.53	76.47	15.982	1.123
550	21.56	78.44	16.394	1.113
500	19.61	80.39	16.892	1.103
450	17.65	82.35	17.211	1.092
400	15.69	84.31	17.621	1.082
350	13.73	86.27	18.031	1.072
300	11.76	88.24	18.442	1.062
250	9.80	90.20	18.852	1.051
200	7.84	92.16	19.261	1.041
150	5.88	94.12	19.670	1.031
100	3.92	96.08	20.081	1.021

LPG SYSTEM DESIGN

Prior to sizing components, initially decide what equipment (such as pumps, vaporizers, and so forth) may be required, if the tank is to be aboveground or belowground, and select the proposed location of the tank and other required equipment on the site. Determine if the propane system will be in constant use or used only periodically, such as for emergency operation or as an occasional substitute for interrupted natural gas.

Calculate the maximum hourly and daily fuel gas demand and determine if this demand is continuous, such as that for a process used all day, or intermittent, such as that used for heating purposes. If only a small part of the demand is continuous, the entire load should be considered continuous.

Storage Tank Sizing and Selection

The storage tank volume is based on one of two factors: a reasonable return schedule for the local supplier, or the amount of liquid propane that has to be vaporized by the ambient air in order to satisfy the maximum demand.

Vaporization directly from a tank, if economically feasible, is used to avoid another mechanical device (a vaporizer) that requires constant maintenance. If a single tank sized to optimum criteria will not provide the required vaporization rate, a single oversized tank or two smaller, separate tanks are often installed if space conditions and initial cost are acceptable.

Tank Size Based on Return Schedule. Using the return schedule, a preliminary starting point for determining actual capacity is a 10-day usable supply for continuous demand and 3 to 5 days usable supply for intermittent, or standby purposes. With the maximum propane level of 85 percent and the minimum level between 10 and 15% of the capacity, the usable tank capacity is about 75 percent of the total tank capacity.

Tank Size Based on Vaporization Rate of Propane. When using vaporization rate as the determining factor in selecting the size of the storage tank, the tank must be large enough to vaporize the maximum flow rate of propane required by the facility with the tank at its minimum capacity and when the outside air temperature is at its lowest. For aboveground tanks, the rate of vaporization is calculated using the wetted area of liquid propane in the tank. For underground tanks, the entire area of the tank is used even if the tank is partially full.

Two methods will be discussed. The first and most accurate method will use various formulas to calculate the wetted area of a tank that will vaporize the required amount of propane. The second, although slightly less accurate, is the direct reading of the vaporization rate from prepared charts. This is a more conservative method and by far the easiest.

Formula Method. Using this method, the wetted area of the proposed aboveground tank necessary to vaporize the required amount of propane will be calculated. If an underground tank is proposed, the area calculated shall be that of the entire tank.

The basic formulas are as follows:

1. The formula for total heat of vaporization from an aboveground tank is:

$$Q = U \times A \times \text{TD} \tag{C17.4}$$

2. The formula for total heat of vaporization from a belowground tank is:

$$Q = U \times A \times 15 \qquad \text{(C17.5)}$$

3. Equation C17.4 transposed to find the wetted area is:

$$Q = \frac{A}{U \times (\text{TD or } 15)} \qquad \text{(C17.6)}$$

4. The formula used to calculate the actual amount of propane vaporized is:

$$V = \frac{Q}{L} \qquad \text{(C17.7)}$$

where Q = the total amount of heat (in Btus) required to vaporize a quantity of liquid propane.

U = rate of heat transfer through the walls of a steel tank, per sq. ft. of wetted area/temperature difference in °F (°C). Generally accepted figures are 2 Btu/ft^2/°F for aboveground tanks, based on severe conditions and 0.5 Btu/ft^2/°F for underground tanks.

A = the wetted surface area of the aboveground tank containing liquid propane, or the entire surface area of an underground tank, in ft^2.

TD = the temperature difference between ambient outside air reached during the coldest part of the day and the temperature of propane in the tank reached during the warmest part of the day, in °F (°C). One factor that must be taken into consideration is the formation of frost on the outside of the storage tank. Since frost acts as an insulation, its formation must be avoided. Table 17.16 will give the minimum temperature difference to avoid frost formation. When predicted conditions are outside the figures required to enter the table, use the actual temperature difference. 15°F (8.3°C) is the generally accepted temperature difference for underground tanks.

V = gallons of propane vaporized under design conditions.

TABLE C17.16 Difference Between Air Temperature and Temperature of Frost Formation, °F

Air temperature		Relative humidity							
°C	°F	20	30	40	50	60	70	80	90
−34.4	−30	—	—	—	—	8.0*	5.0*	2.5*	1.0*
−28.9	−20	—	20.0*	15.0*	11.5*	8.5	5.0	3.0	1.5
−23.3	−10	27.5*	20.5	16.0	12.0	9.0	6.0	3.0	1.5
−17.8	0	29.0	21.5	16.5	12.5	9.0	6.0	4.0	2.0
−12.2	10	30.0	22.5	17.0	13.0	9.5	6.5	4.0	2.0
−6.7	20	31.5	24.0	18.0	14.0	10.0	7.0	4.0	2.0
−1.1	30	33.0	25.0	19.5	15.0	11.0	8.0	5.0	3.0
4.1	40	35.0	27.0	21.0	16.5	12.0	9.0	8.0	8.0

* If the full temperature difference is used in these cases, the minimum tank pressure may be too low for satisfactory performance.

1°F = 0.55°C.

L = latent heat of vaporization of propane, Btu/gal. This is the amount of heat required to change liquid propane to a vapor. Interpolate to find intermediate values when necessary. Refer to Table C17.17.

TABLE C17.17 Latent Heat of Vaporization for Propane

Ambient air temp.		Propane	
°C	°F	Btu per lb	Btu per gal
−40	−40	180.8	765
−34.4	−30	178.7	755
−28.9	−20	176.2	745
−23.3	−10	173.9	735
−17.8	0	171.5	725
−12.2	10	169.0	715
−6.7	20	166.3	704
−1.1	30	163.4	691
4.4	40	160.3	678
10.0	50	156.5	662
15.6	60	152.6	645

The following methodology is used to select a tank with propane vaporization rate as criteria, solving for Eq. C17.6:

1. Establish the lowest predicted ambient air temperature, highest predicted relative humidity, and the required propane gas demand in Btu/hr/gal.
2. Convert Btu/hr demand into gal/hr. Refer to Table C17.2.
3. Transpose Eq. C17.7 to find Q. Refer to Table C17.14 to find L.
4. Substitute all figures into Eq. C17.6 and solve for the wetted area. After calculating the required minimum area, consult manufacturers' catalogs for a size tank providing that figure with the minimum level of propane in the storage tank.

Example 17.2: As an example, calculate the selection of a tank using the minimum area of a tank as the criteria. The following project conditions exist:

1. Lowest predicted temperature: 30°F (−1°C)
2. Highest predicted humidity: 60 percent
3. Required propane demand: 172,000 Btu/hr
4. Type of use: Continuous

First, convert Btu/hr into gal/hr using figure obtained from Table C17.2.

$$172{,}000 \div 91{,}547 = 1.44 \text{ gal/hr}$$

Second, find L using Table C17.17. Entering the table with 30°F, find 163.4 Btu, Third, calculate Q using transposed Eq. C17.7 to read $Q = L \times V$

$$Q = 163.4 \times 1.44$$

$$Q = 235.3$$

Fourth, find TD using Table C17.16.

Fifth, substitute the above figures in Eq. C17.6.

$$A = \frac{235.2}{2 \times 11} = \frac{235.2}{22}$$

The result of the previous calculation is a tank area that will contain the absolute lowest volume of propane that will adequately supply facility needs. A higher volume should be used as an actual "low level." The additional capacity will be required to allow enough time for a delivery before the volume in the tank falls below the level needed to supply the facility. This low level will be a percent of the total capacity of the tank that will be used to select the actual, total capacity of the storage tank in conjunction with the proposed schedule of the supplier. Select a "standard" tank with a slightly greater volume than that calculated. If a single tank selected for adequate vaporization results in a size that is impractical, two tanks can be used. If the size of the tank(s) is still too large or has too high an initial cost, the only other solution is to provide a vaporizer.

Direct Reading Method. Figure C17.11 provides a nomigram for providing direct reading of propane vaporization from larger tanks. Table C17.18 provides a table for a direct reading of propane vaporization from smaller tanks. Both Fig. C17.11 and Table C17.18 are based on a tank that is 25 percent full. Reduce the figures by 10 percent to approximate tanks 15 percent full.

LPG Pipe-Sizing Methods

The tables used for NG pipe sizing are used to size LPG piping. With a specific gravity of 1.52, a conversion factor of 0.63 is used to reduce the flow rate. Dedicated, direct-reading tables for LPG are available in NFPA 54.

Propane is often mixed with air to provide a direct substitute for natural gas. The most common mixture has a value of 1450 Btu/ft^3. With a specific gravity of 1.30, a conversion factor of 0.69 is used to reduce the flow rate.

The method of using the charts was discussed previously for NG pipe sizing.

LPG Pumps

Two pump types are commonly used in LPG service; *sliding vane positive displacement* and *turbine regenerative centrifugal* pumps. In general, the sliding vane positive displacement pump is used for flow from 40 to 350 gpm (3 to 27 l/s). The turbine regenerative pump is generally used for constant flows and pressure when the flow is less than 40 gpm (3 l/s), such as those used to fill propane tanks for home use. Either pump type could be used for any pressure for which it is rated.

To calculate the pump head, add the following:

1. The vapor pressure of the storage tank into which the liquid propane will be pumped. If there is a vapor return line, this will not be a factor.

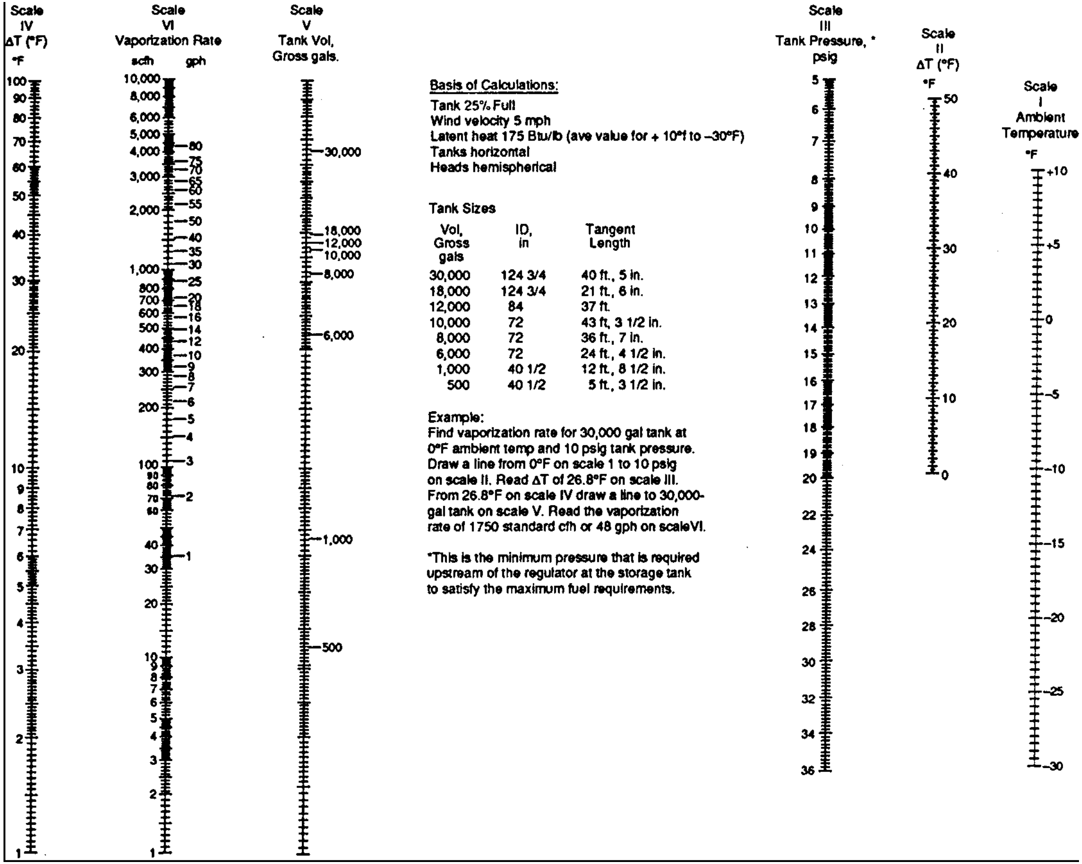


FIGURE C17.11 Vaporization of propane from tanks.

TABLE C17.18 Vaporizing Capacity of LP-Gas Cylinders (cubic feet per hour of propane).(1)

Atmospheric temp.		Cylinder capacity—pounds LP-gas				
°C	°F	20	100	150	300	420
15.6	60	16	31	50	60	95
−1.1	30	10	20	33	46	63
−12.2	10	7	13	21	30	41
−17.8	0	5	10	15	22	30
−23.3	−10	3	6	10	15	19

Note: The above capacities are based on the assumption that the cylinder is 25% filled. It does not include effect of sensible heat. These figures are on the conservative side, and should be used as a guide only. They are based on the cylinder being in the shade in still air, and on continuous withdrawal. Due to beneficial effect of drafts, sunlight, radiation and intermittent operations, most actual installations will have a greater capacity than shown in the table.

1 cfh = 0.028 m^3/h.

TABLE C17.19 Resistance of 1-Ft Lengths of Schedule 40 Steel Pipe (Expressed in Feet of Head of Liquid LP-Gas)(1)

Flow-rate U. S. gal per minute	Nominal pipe size (NPS)						
	1	2	2½	3	4	5	6
10	.007						
20	.028	.008					
30	.060	.017	.007				
40		.031	.012				
50		.048	.020	.004			
60		.070	.028	.009			
70		.095	.038	.013			
80			.050	.017			
90			.063	.021			
100			.078	.025	.006	.002	.001
125				.036	.008	.003	.001
150				.051	.012	.004	.002
175				.088	.016	.005	.002
200				.088	.020	.007	.003
225					.025	.009	.003
250					.031	.010	.004
275					.037	.012	.005
300					.043	.014	.006

1 ft head = 3.0 kPa.
1 gpm = 0.075 l/s.

TABLE C17.20 Resistance of Valves and Fittings to Flow of Propane Liquid Expressed in Equivalent Feet of Pipe

Type valves and fittings		Pipe size						
	NPS	1½	2	2½	3	4	5	6
	DN	32	50	65	80	100	125	150
Straight-through ball, and plug valves, same size as pipe		5	6	8	10	14	17	20
Globe valves, wide open, same size as pipe		40	50	60	80	110	130	160
Angle valves, wide open, same size as pipe		20	25	30	40	55	70	80
Swing check valves, same size as pipe		10	13	16	19	25	31	38
90° elbow, same size as pipe		4	5	6	8	11	13	16
45° elbow, same size as pipe		2	2½	3	3½	5	6	7
Tee, flow-through side outlet, same size as pipe		8	10	13	16	21	27	33
Tee, flow straight through, same size as pipe		2½	3	4	5	7	8½	11
Strainer, same size as pipe		25	60	42	42	50	50	50
Strainer, next larger size than pipe		16	17	14	20	30	30	
Bushing or reducer, to one size larger or smaller		2	2½	3	4	5	6	7

Figures shown represent average resistance-to-flow values.
1 ft = 0.304 m.

TABLE C17.21 Resistance-to-Flow of 50-Ft Lengths of LP-Gas Delivery Hose of Various Sizes and at Various Delivery Rates, 60°F (15.6°C)

Delivery rate		Pressure drop, psi[1]					
l/s	gpm	NPS ½ DN 15	NPS ¾ DN 20	NPS 1 DN 25	NPS 1¼ DN 32	NPS 1½ DN 40	NPS 2 DN 50
0.375	5	8.1	1.1	0.2	0.1	0	0
0.75	10	30.0	4.0	0.9	0.3	0.1	0
1.12	15	64.6	8.5	2.0	0.7	0.3	0
1.5	20	Too high	14.4	3.4	1.0	0.5	0.1
1.9	25	Too high	22.1	5.2	1.7	0.7	0.2
2.25	30	Too high	31.0	7.4	2.4	0.9	0.3
3.0	40	Too high	54.0	12.6	4.2	1.6	0.4
3.75	50	Too high	Too high	19.0	6.4	2.5	0.6
4.5	60	Too high	Too high	26.4	9.0	3.5	0.8
5.25	70	Too high	Too high	35.4	11.9	4.6	1.1
6.0	80	Too high	Too high	46.2	15.5	5.9	1.4
6.75	90	Too high	Too high	56.6	19.0	7.4	1.7
7.5	100	Too high	Too high	69.7	23.4	8.9	2.1

1 psi = 6.9 kPa.

2. The friction loss of the liquid through the piping network. Refer to Table C17.19 for the friction loss of liquid propane through steel piping. Table C17.20 provides the losses through fittings in equivalent feet of steel pipe.
3. The friction losses of liquid propane through delivery hose in psi (kPa). Refer to Table C17.21.
4. Static head difference between the supply and receiving points.
5. The resistance to flow from meters, filler valves, and so forth. Obtain this information from manufacturers.
6. Add all pressure obtained from steps 1 through 5 and add 10 psi (69 kPa) to have some additional pressure available. This figure is the total head requirement for the pump.
7. The flow rate is determined from the specific application.

Piping Materials

The piping materials are the same as for the NG system.

LPG SYSTEM TESTING AND PURGING

After the piping distribution system is installed, it must be first blown clear of any debris, then pressure-tested to ensure a leakproof system, and finally purged and replaced with NG prior to being placed in operation. The pipe terminal releasing gases to the atmosphere during the purging operation shall be located in a safe location and continuously supervised.

The testing and purging are the same as for the NG system.