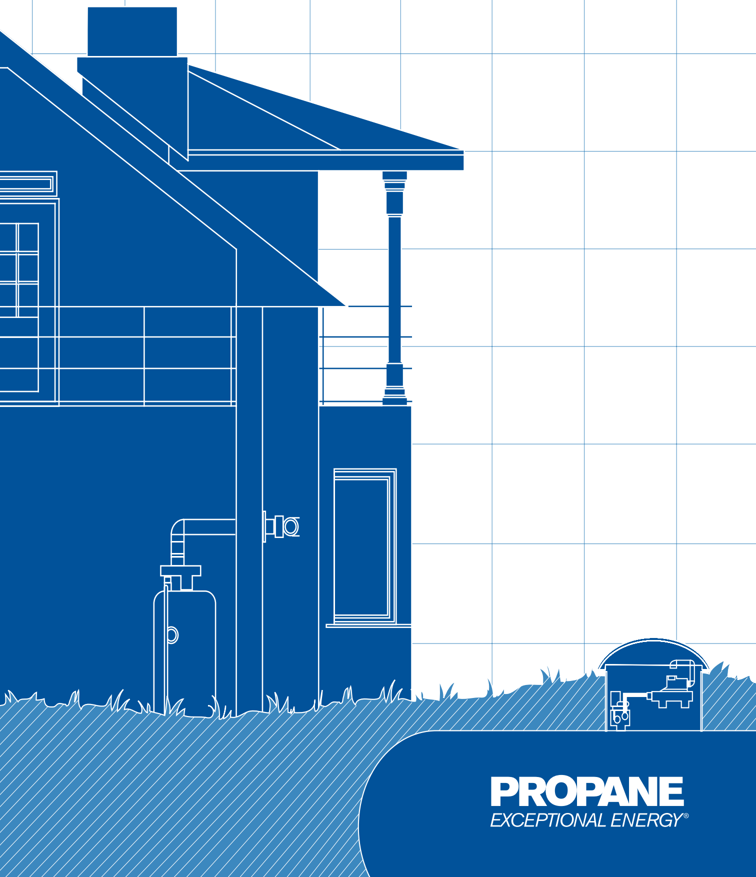
THE PROPANE TECHNICAL POCKET GUIDE



PROPANE
EXCEPTIONAL ENERGY®

The Propane Technical Pocket Guide

The Propane Technical Pocket Guide is intended to be a general reference of information on preparing for the installation of propane systems. It provides key data and answers important questions that are relevant to construction professionals planning to incorporate propane in their construction projects.

This guide is not intended to conflict with federal, state, or local ordinances or pertinent industry regulations, including National Fire Protection Association (NFPA) 54 and 58. These should be observed at all times.

The Propane Technical Pocket Guide must not be considered a replacement for proper training on the installation and start-up of propane systems. Propane system installations should always be performed by trained propane professionals. For more information go to propanesafety.com.

PROPANE education & research COUNCIL

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- Go Green With Propane: An Overview of Propane Gas Systems for Green Residential Construction
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- Condensing Tankless Water Heaters: Using Propane for the Most Efficient Water Heaters on the Market

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Properties of Propane and Natural Gas (Methane)

Table 1A. Approximate Properties of Gases (English)		
PROPERTY	Propane	Natural Gas
	C_3H_8	CH_4
Initial Boiling Point	-44	-259
Specific Gravity of Liquid (Water at 1.0) at 60°F	0.504	n/a
Weight per Gallon of Liquid at 60°F, LB	4.2	n/a
Specific Heat of Liquid, Btu/LB at 60°F	0.63	n/a
Cubic Feet of Vapor per Gallon at 60°F	36.38	n/a
Cubic Feet of Vapor per Pound at 60°F	8.66	23.55
Specific Gravity of Vapor (Air = 1.0) at 60°F	1.5	0.6
Ignition Temperature in Air, °F	920–1120	1301
Maximum Flame Temperature in Air, °F	3595	2834
Cubic Feet of Air Required to Burn One Cubic Foot of Gas	23.68	9.57
Limits of Flammability in Air, % of Vapor in Air-Gas Mix:		
(a) Lower	2.15	5
(b) Upper	9.6	15
Latent Heat of Vaporization at Boiling Point:		
(a) Btu per Pound	184	219
(b) Btu per Gallon	773	n/a
Total Heating Values After Vaporization:		
(a) Btu per Cubic Foot	2,488	1,012
(b) Btu per Pound	21,548	28,875
(c) Btu per Gallon	91,502	n/a

Properties of Gas *(Continued)*

Table 1B. Approximate Properties of Gases (Metric)		
PROPERTY	Propane	Natural Gas
	C_3H_8	CH_4
Initial Boiling Point, °C	-42	-162
Specific Gravity of Liquid (Water at 1.0) at 15.56°C	0.504	n/a
Weight per Cubic Meter of Liquid at 15.56°C, kg	504	n/a
Specific Heat of Liquid, Kilojoule/Kilogram at 15.56°C	1.464	n/a
Cubic Meter of Vapor per Liter at 15.56°C	0.271	n/a
Cubic Meter of Vapor per Kilogram at 15.56°C	0.539	1.470
Specific Gravity of Vapor (Air = 1.0) at 15.56°C	1.50	0.56
Ignition Temperature in Air, °C	493–604	705
Maximum Flame Temperature in Air, °C	1,980	1,557
Cubic Meters of Air Required to Burn One Cubic Meter of Gas	23.86	9.57
Limits of Flammability in Air, % of Vapor in Air-Gas Mix:		
(a) Lower	2.15	5.0
(b) Upper	9.6	15.0
Latent Heat of Vaporization at Boiling Point:		
(a) Kilojoule per Kilogram	428	509
(b) Kilojoule per Liter	216	n/a
Total Heating Values After Vaporization:		
(a) Kilojoule per Cubic Meter	92,430	37,706
(b) Kilojoule per Kilogram	49,920	55,533
(c) Kilojoule per Liter	25,140	n/a

Table 1C. Energy Content and Environmental Impact of Various Energy Sources					
	Propane (per ft^3)	Methane	Propane (per gallon)	Fuel Oil	Electricity
Energy Value	2,524 Btu/ft^3	1,012 Btu/ft^3	91,500 Btu/gal	139,400 Btu/gal	3,413 Btu/ kWh
CO_2 emissions (lbs/ MMBtu)	139.2	115.3	139.2	161.4	389.5
Source Energy Multipliers*	1.151	1.092	1.151	1.158	3.365

*Source Energy Multiplier is the total units of energy that go into generation, processing, and delivery for a particular energy source to produce one unit of energy at the site.

Vapor Pressure of Gas

Vapor pressure can be defined as the force exerted by a gas or liquid attempting to escape from a container. This pressure moves gas along the pipe or tubing to the appliance burner.

Outside temperature greatly affects container pressure. Lower temperature means lower container pressure. Too low a container pressure means that not enough gas is able to get to the appliance.

The table below shows vapor pressures for propane and butane at various outside temperatures.

Table 2. Vapor Pressures

TEMPERATURE		Approximate Vapor Pressure, PSIG (bar) Propane → to → Butane						
°F	°C	100%	80/20	60/40	50/50	40/60	20/80	100%
-40	-40	3.6 (0,25)	-	-	-	-	-	-
-30	-34,4	8 (0,55)	4.5 (0,31)	-	-	-	-	-
-20	-28,9	13.5 (0,93)	9.2 (0,63)	4.9 (0,34)	1.9 (0,13)	-	-	-
-10	-23,3	20 (1,4)	16 (1,1)	9 (0,62)	6 (0,41)	3.5 (0,24)	-	-
0	-17,8	28 (1,9)	22 (1,5)	15 (1,0)	11 (0,76)	7.3 (0,50)	-	-
10	-12,2	37 (2,6)	29 (2,0)	20 (1,4)	17 (1,2)	13 (0,90)	3.4 (0,23)	-
20	-6,7	47 (3,2)	36 (2,5)	28 (1,9)	23 (1,6)	18 (1,2)	7.4 (0,51)	-
30	-1,1	58 (4,0)	45 (3,1)	35 (2,4)	29 (2,0)	24 (1,7)	13 (0,9)	-
40	4,4	72 (5,0)	58 (4,0)	44 (3,0)	37 (2,6)	32 (2,2)	18 (1,2)	3 (0,21)
50	10	86 (5,9)	69 (4,8)	53 (3,7)	46 (3,2)	40 (2,8)	24 (1,7)	6.9 (0,58)
60	15,6	102 (7,0)	80 (5,5)	65 (4,5)	56 (3,9)	49 (3,4)	30 (2,1)	12 (0,83)
70	21,1	127 (8,8)	95 (6,6)	78 (5,4)	68 (4,7)	59 (4,1)	38 (2,6)	17 (1,2)
80	26,7	140 (9,7)	125 (8,6)	90 (6,2)	80 (5,5)	70 (4,8)	46 (3,2)	23 (1,6)
90	32,2	165 (11,4)	140 (9,7)	112 (7,7)	95 (6,6)	82 (5,7)	56 (3,9)	29 (2,0)
100	37,8	196 (13,5)	168 (11,6)	137 (9,4)	123 (8,5)	100 (6,9)	69 (4,8)	36 (2,5)
110	43,3	220 (15,2)	185 (12,8)	165 (11,4)	148 (10,2)	130 (9,0)	80 (5,5)	45 (3,1)

Table adapted from LP-Gas Serviceman's Handbook 2012

Determining Total Load

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. If specific appliance capacity information is not available, Table 3A below will be useful. Remember to allow for appliances that may be installed at a later date.

If the propane load in standard cubic feet per hour (SCFH) is desired, divide the Btu/hr load by 2,488 to get SCFH. Conversely, the Btu/hr capacity can be obtained from SCFH by multiplying the SCFH figure by 2,488.

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

Table 3A. Gas Required for Common Appliances

APPLIANCE	Approximate Input Btu/hr
Warm Air Furnace	
Single Family	60,000–120,000
Multifamily, per Unit	40,000–60,000
Hydronic Boiler, Space Heating	
Single Family	80,000–140,000
Multifamily, per Unit	50,000–80,000
Hydronic Boiler, Space and Water Heating	
Single Family	100,000–200,000
Multifamily, per Unit	50,000–100,000
Range, Freestanding, Domestic	50,000–90,000
Built-In Oven or Broiler Unit, Domestic	14,000–16,000
Built-In Top Unit, Domestic	40,000–85,000
Water Heater, Storage, 30 to 40 gal. Tank	25,000–50,000
Water Heater, Storage, 50 gal. Tank	30,000–55,000
Water Heater, Tankless	30,000–55,000
2.5 GPM	
3 GPM	115,000–125,000
4 GPM	125,000–150,000
Water Heater, Domestic, Circulating or Side-Arm	155,000–200,000
Refrigerator	1,500–2,000
Clothes Dryer, Type 1 (Domestic)	18,000–22,000
Gas Fireplace Direct Vent	20,000–90,000
Gas Log	35,000–90,000
Barbecue	40,000–80,000
Gas Light	1,400–2,800

Table adapted from Newport Partners, 2011.

A variety of mechanical systems are available for space heating and water heating in homes. These systems have varying energy sources and varying efficiency levels. Table 3B below provides simple calculations that allow contractors and homeowners to estimate the dollars per million Btus depending on the equipment type, efficiency, and energy price. The "$/MMBtu" figure can be compared across different options to evaluate them.

Table 3B. Operating Costs and Equipment Efficiencies of Residential Space and Water Heating Systems

SPACE HEATING	Pricing Estimation Formula ($/MMBtu)	Typical Equipment Efficiency Ranges for Newer Systems	
Propane (furnace or boiler)	(10.9 x $/gal) / (AFUE/100)	AFUE: 78–98	
Natural Gas (furnace or boiler)	(10 x $/therm) / (AFUE/100)	AFUE: 78–98	
Fuel Oil (furnace or boiler)	(7.2 x $/gal) / (AFUE/100)	AFUE: 78–95	
Electric Resistance	293 x $/kWh	COP: 1.0	
Electric Air Source Heat Pump	(1000 x $/kWh) / HSPF	HSPF: 7.7–13.0	
Electric Ground Source Heat Pump	(293 x $/kWh) / COP	COP: 3.0–4.7	
WATER HEATING	**Pricing Estimation Formula ($/MMBtu)**	**Typical Storage Water Heater Energy Factors (EF)**	**Typical Instantaneous Water Heater Energy Factor (EF)**
Propane	(10.9 x $/gal)/EF	0.59–0.67*	0.82–0.98
Methane	(10 x $/therm)/EF	0.59–0.70*	0.82–0.98
Fuel Oil	(7.2 x $/gal)/EF	0.51–0.68	—
Electric Resistance	(293 x $/kWh)/EF	0.90–0.95	0.93–1.0
Electric Air Source Heat Pump	(293 x $/kWh)/EF	2.0–2.51	—

*Residential and commercial units are available with thermal efficiencies up to 96%.

Vaporization Rates

The factors affecting vaporization include wetted surface area of the container, liquid level in the container, temperature and humidity surrounding the container, and whether the container is aboveground or underground.

The temperature of the liquid is proportional to the outside air temperature, and the wetted surface area is the tank surface area in contact with the liquid. Therefore, when the outside air temperature is lower or the container has less liquid in it, the vaporization rate of the container is a lower value.

To determine the proper size of ASME storage tanks, it is important to consider the lowest winter temperature at the location.

See page 10 for more information.

Vaporization Rates for ASME Storage Tanks

A number of assumptions were made in calculating the Btu figures listed in Table 4, below:

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

Although none of these conditions may apply, Table 4 can still serve as a good rule of thumb in estimating what a particular tank size will provide under various temperatures. This method uses ASME tank dimensions, liquid level, and a constant value for each 10 percent of liquid to estimate the vaporization capacity of a given tank size at 0°F. Continuous loading is not a very common occurrence on domestic installations, but under continuous loading the withdrawal rates in Table 4 should be multiplied by 0.25.

Table 4. Maximum Intermittent Withdrawal Rate (Btu/hr) Without Tank Frosting* If Lowest Outdoor Temperature (Average for 24 Hours) Reaches ...

TEMPERATURE		Tank Size, Gallons (l)			
		150 (568)	250 (946)	500 (1893)	1000 (3785)
40°F	4°C	214,900	288,100	478,800	852,800
30°F	-1°C	187,000	251,800	418,600	745,600
20°F	-7°C	161,800	216,800	360,400	641,900
10°F	-12°C	148,000	198,400	329,700	587,200
0°F	-18°C	134,700	180,600	300,100	534,500
-10°F	-23°C	132,400	177,400	294,800	525,400
-20°F	-29°C	108,800	145,800	242,300	431,600
-30°F	-34°C	107,100	143,500	238,600	425,000

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

Container Location and Installation

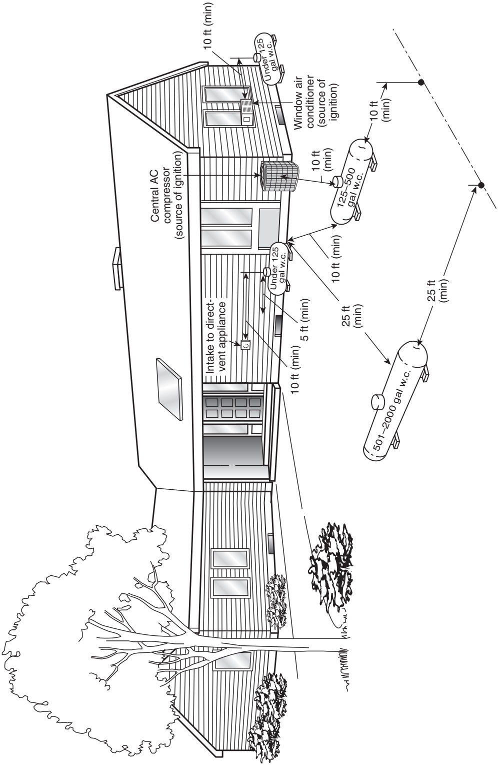
Once the proper size of the ASME storage tank has been determined, careful attention must be given to the most convenient yet safe place for its location on the customer's property.

The container should be placed in a location pleasing to the customer but not conflicting with state and local regulations or NFPA 58, Storage and Handling of Liquefied Petroleum Gases. Refer to this standard and consult with your propane professional to determine the appropriate placement of propane containers.

In general, storage tanks should be placed in an accessible location for filling. Aboveground tanks should be supported by concrete blocks of appropriate size and reinforcement. All propane storage tanks should be located away from vehicular traffic.

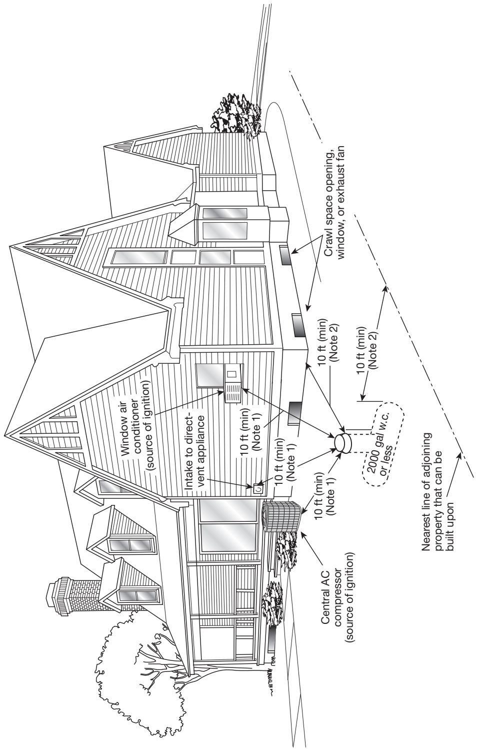
For ASME containers, the distance from any building openings, external sources of ignition, and intakes to direct-vented gas appliances or mechanical ventilation systems are a critical consideration. See Figures 5 and 6 on pages 12 and 13, respectively.

Refer to NFPA 58 for the minimum distances that these containers must be placed from a building or other objects.



1. Regardless of its size, any ASME tank filled on site must be located so that the filling connection and fixed maximum liquid level gauge are at least 10 ft from any external source of ignition (e.g., open flame, window AC, compressor), intake to direct-vented gas appliances or intake to a mechanical ventilation system.
2. The distance may be reduced to no less than 10 ft for a single container of 1200 gal (4.5 m^3) water capacity or less, provided such container is at least 25 ft from any other LP-Gas container of more than 125 gal (0.5 m^3) water capacity.

Figure 5. *Aboveground ASME containers. Reproduced with permission from NFPA 58-2011,* Liquefied Petroleum Gas Code, *Copyright © 2010, National Fire Protection Association. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.*



1. The relief valve, filling connection, and fixed maximum liquid level gauge vent connection at the container must be at least 10 ft from any exterior source of ignition, openings into direct-vent appliances, or mechanical ventilation air intakes.
2. No part of an underground container can be less than 10 ft from an important building or line of adjoining property that can be built upon.

Figure 6. *Underground ASME containers. Reproduced with permission from NFPA 58-2011,* Liquefied Petroleum Gas Code, *Copyright © 2010, National Fire Protection Association. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.*

Table 7. Pipe Sizing Between Second-Stage Regulator and Appliance

MAXIMUM UNDILUTED PROPANE CAPACITIES BASED ON 10.0 PSI INLET PRESSURE AND 1.0 PSI PRESSURE DROP. (BASED ON A 1.52 SPECIFIC-GRAVITY GAS.)

	Nominal Pipe Size, Schedule 40								
Piping Length, Feet	1/2 in. (0.622)	3/4 in. (0.824)	1 in. (1.049)	1-1/4 in. (1.38)	1-1/2 in. (1.61)	2 in. (2.067)	3 in. (3.068)	3-1/2 in. (3.548)	4 in. (4.026)
10	291	608	1146	2353	3525	6789	19130	28008	39018
20	200	418	788	1617	2423	4666	13148	19250	26817
30	161	336	632	1299	1946	3747	10558	15458	21535
40	137	287	541	1111	1665	3207	9036	13230	18431
50	122	255	480	985	1476	2842	8009	11726	16335
60	110	231	435	892	1337	2575	7256	10625	14801
80	94	198	372	764	1144	2204	6211	9093	12668
100	84	175	330	677	1014	1954	5504	8059	11227
125	74	155	292	600	899	1731	4878	7143	9950
150	67	141	265	544	815	1569	4420	6472	9016
200	58	120	227	465	697	1343	3783	5539	7716
250	51	107	201	412	618	1190	3353	4909	6839
300	46	97	182	374	560	1078	3038	4448	6196
350	43	89	167	344	515	992	2795	4092	5701
400	40	83	156	320	479	923	2600	3807	5303

Note: Capacities are in 1000 Btu/hr.

Table 8. Maximum Capacity of CSST*

EHD** FLOW DESIGNATION	IN THOUSANDS OF BTU/HR OF UNDILUTED PROPANE AT A PRESSURE OF 11-INCHES W.C. AND A PRESSURE DROP OF 0.5-INCH W.C. (BASED ON A 1.52 SPECIFIC GRAVITY GAS)																
	Tubing Length, Feet																
	5	10	15	20	25	30	40	50	60	70	80	90	100	150	200	250	300
13	72	50	39	34	30	28	23	20	19	17	15	15	14	11	9	8	8
15	99	69	55	49	42	39	33	30	26	25	23	22	20	15	14	12	11
18	181	129	104	91	82	74	64	58	53	49	45	44	41	31	28	25	23
19	211	150	121	106	94	87	74	66	60	57	52	50	47	36	33	30	26
23	355	254	208	183	164	151	131	118	107	99	94	90	85	66	60	53	50
25	426	303	248	216	192	177	153	137	126	117	109	102	98	75	69	61	57
30	744	521	422	365	325	297	256	227	207	191	178	169	159	123	112	99	90
31	863	605	490	425	379	344	297	265	241	222	208	197	186	143	129	117	107

*Table includes losses for four 90° bends and two end fittings. Tubing runs with larger numbers of bend and/or fittings shall be increased by an equivalent length of tubing to the following equation: $L = 1.3n$ where L is the additional length (ft) of tubing and n is the number of additional fittings and/or bends.

**EHD (Equivalent Hydraulic Diameter) A measure of the relative hydraulic efficiency between different tubing sizes. The greater the value of EHD, the greater the gas capacity of the tubing.

Gas Piping Inlet Positioning

Just like tanks, propane pressure regulators come with pipe-size and installation-distance requirements. Regulators installed on the gas piping system at the side of buildings cannot be placed closer than 3 feet horizontally from any building opening, such as a window well, that's lower than the installed regulator. Nor can they be placed closer than 5 feet from any source of ignition, such as an AC compressor. Additional regulations, as well as regulator manufacturer's instructions, may apply. Check with a propane professional first to ensure you comply with interior gas piping inlet positioning requirements.

Conversion Factors

Multiply	By	To Obtain
LENGTH AND AREA		
Millimeters	0.0394	Inches
Meters	3.2808	Feet
Sq. Centimeters	0.1550	Sq. Inches
Sq. Meters	10.764	Sq. Feet
VOLUME AND MASS		
Cubic Meters	35.315	Cubic Feet
Liters	0.0353	Cubic Feet
Gallons	0.1337	Cubic Feet
Cubic cm.	0.061	Cubic Inches
Liters	2.114	Pints (US)
Liters	0.2642	Gallons (US)
Kilograms	2.2046	Pounds
Tonnes	1.1024	Tons (US)
PRESSURE AND FLOW RATE		
Millibars	0.4018	Inches w.c.
Ounces/sq. in.	1.733	Inches w.c.
Inches w.c.	0.0361	Pounds/sq. in.
Bars	14.50	Pounds/sq. in.
Kilopascals	0.1450	Pounds/sq. in.
Kilograms/sq. cm.	14.222	Pounds/sq. in.
Pounds/sq. in.	0.068	Atmospheres
Liters/hr.	0.0353	Cubic Feet/hr.
Cubic Meters/hr.	4.403	Gallons/min.
MISCELLANEOUS		
Kilojoules	0.9478	Btu
Calories, kg	3.968	Btu
Watts	3.414	Btu/hr
Btu	0.00001	Therms
Megajoules	0.00948	Therms

Conversion Factors

Multiply	By	To Obtain
LENGTH AND AREA		
Inches	25.4	Millimeters
Feet	0.3048	Meters
Sq. Inches	6.4516	Sq. Centimeters
Sq. Feet	0.0929	Sq. Meters
VOLUME AND MASS		
Cubic Feet	0.0283	Cubic Meters
Cubic Feet	28.316	Liters
Cubic Feet	7.481	Gallons
Cubic Inches	16.387	Cubic cm.
Pints (US)	0.473	Liters
Gallons (US)	3.785	Liters
Pounds	0.4535	Kilograms
Tons (US)	0.9071	Tonnes
PRESSURE AND FLOW RATE		
Inches w.c.	2.488	Millibars
Inches w.c.	0.577	Ounces/sq. in.
Pounds/sq. in.	27.71	Inches w.c.
Pounds/sq. in.	0.0689	Bars
Pounds/sq. in.	6.895	Kilopascals
Pounds/sq. in.	0.0703	Kilograms/sq. cm.
Atmospheres	14.696	Pounds/sq. in.
Cubic Feet/hr.	28.316	Liters/hr.
Gallons/min.	0.2271	Cubic Meters/hr.
MISCELLANEOUS		
Btu	1.055	Kilojoules
Btu	0.252	Calories, kg
Btu/hr	0.293	Watts
Therms	100,000	Btu
Therms	105.5	Megajoules

Temperature Conversion

Table 9. Temperature Conversion					
°F	°C	°F	°C	°F	°C
-40	-40	30	-1.1	90	32.2
-30	-34.4	32	0	100	37.8
-20	-28.9	40	4.4	110	43.3
-10	-23.3	50	10.0	120	48.9
0	-17.8	60	15.6	130	54.4
10	-12.2	70	21.1	140	60.0
20	-6.7	80	26.7	150	65.6

Notes

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The Propane Education & Research Council was authorized by the U.S. Congress with the passage of Public Law 104-284, the Propane Education and Research Act (PERA), signed into law on October 11, 1996. The mission of the Propane Education & Research Council is to promote the safe, efficient use of odorized propane gas as a preferred energy source.