

CHAPTER 38

UNITS AND CONVERSIONS

Table 1 Conversions to I-P and SI Units
(Multiply I-P values by conversion factors to obtain SI; divide SI values by conversion factors to obtain I-P)

Multiply I-P	By	To Obtain SI	Multiply I-P	By	To Obtain SI
acre (43,560 ft ²).....	0.4047	ha	in·lb _f (torque or moment).....	113	mN·m
.....	4046.873	m ²	in ²	645.16	mm ²
atmosphere (standard).....	*101.325	kPa	in ³ (volume).....	16.3874	mL
bar.....	*100	kPa	in ³ /min (SCIM).....	0.273117	mL/s
barrel (42 U.S. gal, petroleum).....	159.0	L	in ³ (section modulus).....	16,387	mm ³
.....	0.1580987	m ³	in ⁴ (section moment).....	416,231	mm ⁴
Btu (International Table).....	1055.056	J	kWh.....	*3.60	MJ
Btu (thermochemical).....	1054.350	J	kW/1000 cfm.....	2.118880	kJ/m ³
Btu/ft ² (International Table).....	11,356.53	J/m ²	kilopond (kg force).....	9.81	N
Btu/ft ³ (International Table).....	37,258.951	J/m ³	kip (1000 lb _f).....	4.45	kN
Btu/gal.....	278,717.1765	J/m ³	kip/in ² (ksi).....	6.895	MPa
Btu·ft/h·ft ² ·°F.....	1.730735	W/(m ² ·K)	litre.....	*0.001	m ³
Btu·in/h·ft ² ·°F (thermal conductivity <i>k</i>).....	0.1442279	W/(m·K)	met.....	58.15	W/m ²
Btu/h.....	0.2930711	W	micron (μm) of mercury (60°F).....	133	mPa
Btu/h·ft ²	3.154591	W/m ²	mile.....	1.609	km
Btu/h·ft ² ·°F (overall heat transfer coefficient <i>U</i>).....	5.678263	W/(m ² ·K)	mile, nautical.....	*1.852	km
Btu/lb.....	*2.326	kJ/kg	mile per hour (mph).....	1.609344	km/h
Btu/lb·°F (specific heat <i>c_p</i>).....	*4.1868	kJ/(kg·K)	0.447	m/s
bushel (dry, U.S.).....	0.0352394	m ³	millibar.....	*0.100	kPa
calorie (thermochemical).....	*4.184	J	mm of mercury (60°F).....	0.133	kPa
centipoise (dynamic viscosity μ).....	*1.00	mPa·s	mm of water (60°F).....	9.80	Pa
centistokes (kinematic viscosity ν).....	*1.00	mm ² /s	ounce (mass, avoirdupois).....	28.35	g
clo.....	0.155	(m ² ·K)/W	ounce (force or thrust).....	0.278	N
dyne.....	1.0 × 10 ⁻⁵	N	ounce (liquid, U.S.).....	29.6	mL
dyne/cm ²	*0.100	Pa	ounce inch (torque, moment).....	7.06	mN·m
EDR hot water (150 Btu/h).....	43.9606	W	ounce (avoirdupois) per gallon.....	7.489152	kg/m ³
EDR steam (240 Btu/h).....	70.33706	W	perm (permeance at 32°F).....	5.72135 × 10 ⁻¹¹	kg/(Pa·s·m ²)
EER.....	0.293	COP	perm inch (permeability at 32°F).....	1.45362 × 10 ⁻¹²	kg/(Pa·s·m)
ft.....	*0.3048	m	pint (liquid, U.S.).....	4.73176 × 10 ⁻⁴	m ³
.....	*304.8	mm	pound		
ft/min, fpm.....	*0.00508	m/s	lb (avoirdupois, mass).....	0.453592	kg
ft/s, fps.....	*0.3048	m/s	453.592	g
ft of water.....	2989	Pa	lb _f (force or thrust).....	4.448222	N
ft of water per 100 ft pipe.....	98.1	Pa/m	lb _f /ft (uniform load).....	14.59390	N/m
ft ²	0.092903	m ²	lb/ft·h (dynamic viscosity μ).....	0.4134	mPa·s
ft ² ·h·°F/Btu (thermal resistance <i>R</i>).....	0.176110	(m ² ·K)/W	lb/ft·s (dynamic viscosity μ).....	1490	mPa·s
ft ² /s (kinematic viscosity ν).....	92,900	mm ² /s	lb _f ·s/ft ² (dynamic viscosity μ).....	47.88026	Pa·s
ft ³	28.316846	L	lb/h.....	0.000126	kg/s
.....	0.02832	m ³	lb/min.....	0.007559	kg/s
ft ³ /min, cfm.....	0.471947	L/s	lb/h [steam at 212°F (100°C)].....	0.2843	kW
ft ³ /s, cfs.....	28.316845	L/s	lb _f /ft ²	47.9	Pa
ft·lb _f (torque or moment).....	1.355818	N·m	lb/ft ²	4.88	kg/m ²
ft·lb _f (work).....	1.356	J	lb/ft ³ (density, ρ).....	16.0	kg/m ³
ft·lb _f /lb (specific energy).....	2.99	J/kg	lb/gallon.....	120	kg/m ³
ft·lb _f /min (power).....	0.0226	W	ppm (by mass).....	*1.00	mg/kg
footcandle.....	10.76391	lx	psi.....	6.895	kPa
gallon (U.S., *231 in ³).....	3.785412	L	quad (10 ¹⁵ Btu).....	1.055	EJ
gph.....	1.05	mL/s	quart (liquid, U.S.).....	0.9463	L
gpm.....	0.0631	L/s	square (100 ft ²).....	9.29	m ²
gpm/ft ²	0.6791	L/(s·m ²)	tablespoon (approximately).....	15	mL
gpm/ton refrigeration.....	0.0179	mL/J	teaspoon (approximately).....	5	mL
grain (1/7000 lb).....	0.0648	g	therm (U.S.).....	105.5	MJ
gr/gal.....	17.1	g/m ³	ton, long (2240 lb).....	1.016	Mg
gr/lb.....	0.143	g/kg	ton, short (2000 lb).....	0.907	Mg; t (tonne)
horsepower (boiler) (33,470 Btu/h).....	9.81	kW	ton, refrigeration (12,000 Btu/h).....	3.517	kW
horsepower (550 ft·lb _f /s).....	0.7457	kW	torr (1 mm Hg at 0°C).....	133	Pa
inch.....	*25.4	mm	watt per square foot.....	10.76	W/m ²
in. of mercury (60°F).....	3.37	kPa	yd.....	*0.9144	m
in. of water (60°F).....	249	Pa	yd ²	0.8361	m ²
in/100 ft, thermal expansion.....	0.833	mm/m	yd ³	0.7646	m ³

*Conversion factor is exact.

Notes: 1. Units are U.S. values unless noted otherwise.

2. Litre is a special name for the cubic decimetre. 1 L = 1 dm³ and 1 mL = 1 cm³.

The preparation of this chapter is assigned to TC 1.6, Terminology.

Table 2 Conversion Factors

Pressure psi	in. of water (60°F)	in. Hg (32°F)	atmosphere	mm Hg (32°F)	bar	kgf/cm ²	pascal
1	= 27.708	= 2.0360	= 0.068046	= 51.715	= 0.068948	= 0.07030696	= 6894.8
0.036091	1	0.073483	2.4559 × 10 ⁻³	1.8665	2.4884 × 10 ⁻³	2.537 × 10 ⁻³	248.84
0.491154	13.609	1	0.033421	25.400	0.033864	0.034532	3386.4
14.6960	407.19	29.921	1	760.0	1.01325*	1.03323	1.01325 × 10 ^{5*}
0.0193368	0.53578	0.03937	1.31579 × 10 ⁻³	1	1.3332 × 10 ⁻³	1.3595 × 10 ⁻³	133.32
14.5038	401.86	29.530	0.98692	750.062	1	1.01972*	10 ^{5*}
14.223	394.1	28.959	0.96784	735.559	0.980665*	1	9.80665 × 10 ^{4*}
1.45038 × 10 ⁻⁴	4.0186 × 10 ⁻³	2.953 × 10 ⁻⁴	9.8692 × 10 ⁻⁶	7.50 × 10 ⁻³	10 ^{-5*}	1.01972 × 10 ^{-5*}	1

Mass	lb (avoir.)	grain	ounce (avoir.)	kg
1	= 7000*	= 16*	= 0.45359	
1.4286 × 10 ⁻⁴	1	2.2857 × 10 ⁻³	6.4800 × 10 ⁻⁵	
0.06250	437.5*	1	0.028350	
2.20462	1.5432 × 10 ⁴	35.274	1	

Volume	cubic inch	cubic foot	gallon	litre	cubic metre (m ³)
1	= 5.787 × 10 ⁻⁴	= 4.329 × 10 ⁻³	= 0.0163871	= 1.63871 × 10 ⁻⁵	
1728*	1	7.48052	28.317	0.028317	
231.0*	0.13368	1	3.7854	0.0037854	
61.02374	0.035315	0.264173	1	0.001*	
6.102374 × 10 ⁴	35.315	264.173	1000*	1	

Energy	Btu	ft·lb _f	calorie (cal)	joule (J) = watt-second (W·s)	watt-hour (W·h)
1	= 778.17	= 251.9958	= 1055.056	= 0.293071	
Note: MBtu, which is 1000 Btu, is confusing and is not used in the Handbook.	1.2851 × 10 ⁻³	1	0.32383	1.355818	3.76616 × 10 ⁻⁴
	3.9683 × 10 ⁻³	3.08803	1	4.1868*	1.163 × 10 ^{-3*}
	9.4782 × 10 ⁻⁴	0.73756	0.23885	1	2.7778 × 10 ⁻⁴
	3.41214	2655.22	859.85	3600*	1

Density	lb/ft ³	lb/gal	g/cm ³	kg/m ³
1	= 0.133680	= 0.016018	= 16.018463	
7.48055	1	0.119827	119.827	
62.4280	8.34538	1	1000*	
0.0624280	0.008345	0.001*	1	

Specific Volume	ft ³ /lb	gal/lb	cm ³ /g	m ³ /kg
1	= 7.48055	= 62.4280	= 0.0624280	
0.133680	1	8.34538	0.008345	
0.016018	0.119827	1	0.001*	
16.018463	119.827	1000*	1	

Viscosity (absolute)	1 poise = 1 dyne-sec/cm ² = 0.1 Pa·s = 1 g/(cm·s)				
	poise	lb _f ·s/ft ²	lb _f ·h/ft ²	kg/(m·s) = N·s/m ²	lb _m /ft·s
1	= 2.0885 × 10 ⁻³	= 5.8014 × 10 ⁻⁷	= 0.1*	= 0.0671955	
478.8026	1	2.7778 × 10 ⁻⁴	47.88026	32.17405	
1.72369 × 10 ⁶	3600*	1	1.72369 × 10 ⁵	1.15827 × 10 ⁵	
10*	0.020885	5.8014 × 10 ⁻⁶	1	0.0671955	
14.8819	0.031081	8.6336 × 10 ⁻⁶	1.4882	1	

Temperature Scale	Temperature				Temperature Interval					
	K	°C	°R	°F	K	°C	°R	°F		
Kelvin	x K =	x	x - 273.15	1.8x	1.8x - 459.67	1 K =	1	1	9/5 = 1.8	9/5 = 1.8
Celsius	x°C =	x + 273.15	x	1.8x + 491.67	1.8x + 32	1°C =	1	1	9/5 = 1.8	9/5 = 1.8
Rankine	x°R =	x/1.8	(x - 491.67)/1.8	x	x - 459.67	1°R =	5/9	5/9	1	1
Fahrenheit	x°F =	(x + 459.67)/1.8	(x - 32)/1.8	x + 459.67	x	1°F =	5/9	5/9	1	1

Notes: Conversions with * are exact.
The Btu and calorie are based on the International Table.

All temperature conversions and factors are exact.
The term centigrade is obsolete and should not be used.

When making conversions, remember that a converted value is no more precise than the original value. For many applications, rounding off the converted value to the same number of significant

figures as those in the original value provides sufficient accuracy.
See ANSI Standard SI-10-1997 (available from ASTM or IEEE) for additional conversions.

Related Commercial Resources