

APPENDIX A

MISCELLANEOUS DATA AND CONVERSION FACTORS

SOME USEFUL WEIGHTS AND MEASURES

Unit Of Measure	Equivalent	
grain	0.002	ounces
gram	0.04	ounces
ounce	28.35	grams
kilogram	2.21	pounds
pound	0.45	kilograms
pound (troy)	12	ounces
ton (short)	2000	pounds
ton (long)	2240	pounds
ton (metric)	2200	pounds
ton (shipping)	40	feet ³
centimeter	0.39	inches
inch	2.54	centimeters
foot	30.48	centimeters
meter	1.09	yards
yard	0.91	meters
mile	1.61	kilometers
centimeter ²	0.16	inches ²
inch ²	6.45	centimeters ²
foot ²	0.09	meters ²
meter ²	1.2	yards ²
yard ²	0.84	meters ²
mile ²	2.59	kilometers ²
centimeter ³	0.061	inches ³
inch ³	16.39	centimeters ³
foot ³	283.17	centimeters ³
foot ³	1728	inches ³

SOME USEFUL WEIGHTS AND MEASURES (cont.)

Unit Of Measure	Equivalent	
meter ³	1.31	yards ³
yard ³	0.77	meters ³
cord	128	feet ³
cord	4	meters ³
peck	8	quarts
bushel (dry)	4	pecks
bushel	2150.4	inches ³
gallon (U. S.)	231	inches ³
barrel	31.5	gallons
hogshead	2	barrels
township	36	miles ²
hectare	2.5	acres

MISCELLANEOUS DATA

One cubic foot of anthracite coal weighs about 53 pounds.

One cubic foot of bituminous coal weighs from 47 to 50 pounds.

One ton of coal is equivalent to two cords of wood for steam purposes.

A gallon of water (U. S. Standard) weighs 8.33 pounds and contains 231 cubic inches.

There are 9 square feet of heating surface to each square foot of grate surface.

A cubic foot of water contains 7.5 gallons and 1728 cubic inches, and weighs 62.5 lbs.

Each nominal horsepower of a boiler requires 30 to 35 pounds of water per hour.

A horsepower is equivalent to raising 33,000 pounds one foot per minute, or 550 pounds one foot per second.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by 0.434.

TYPICAL PARAMETERS OF VARIOUS FUELS^a

Type Of Fuel	Heating Value		Sulfur % (by weight)	Ash % (by weight)
	kcal	Btu		
Solid Fuels				
Bituminous Coal	7,200/kg	13,000/lb	0.6-5.4	4-20
Anthracite Coal	6,810/kg	12,300/lb	0.5-1.0	7.0-16.0
Lignite (@ 35% moisture)	3,990/kg	7,200/lb	0.7	6.2
Wood (@ 40% moisture)	2,880/kg	5,200/lb	N	1-3
Bagasse (@ 50% moisture)	2,220/kg	4,000/lb	N	1-2
Bark (@ 50% moisture)	2,492/kg	4,500/lb	N	1-3 ^b
Coke, Byproduct	7,380/kg	13,300/lb	0.5-1.0	0.5-5.0
Liquid Fuels				
Residual Oil	9.98 x 10 ⁶ /m ³	150,000/gal	0.5-4.0	0.05-0.1
Distillate Oil	9.30 x 10 ⁶ /m ³	140,000/gal	0.2-1.0	N
Diesel	9.12 x 10 ⁶ /m ³	137,000/gal	0.4	N
Gasoline	8.62 x 10 ⁶ /m ³	130,000/gal	0.03-0.04	N
Kerosene	8.32 x 10 ⁶ /m ³	135,000/gal	0.02-0.05	N
Liquid Petroleum Gas	6.25 x 10 ⁶ /m ³	94,000/gal	N	N
Gaseous Fuels				
Natural Gas	9,341/m ³	1,050/SCF	N	N
Coke Oven Gas	5,249/m ³	590/SCF	0.5-2.0	N
Blast Furnace Gas	890/m ³	100/SCF	N	N

^a N = negligible.

^b Ash content may be considerably higher when sand, dirt, etc., are present.

THERMAL EQUIVALENTS FOR VARIOUS FUELS

Type Of Fuel	kcal	Btu (gross)
Solid fuels		
Bituminous coal	$(5.8 \text{ to } 7.8) \times 10^6/\text{Mg}$	$(21.0 \text{ to } 28.0) \times 10^6/\text{ton}$
Anthracite coal	$7.03 \times 10^6/\text{Mg}$	$25.3 \times 10^6/\text{ton}$
Lignite	$4.45 \times 10^6/\text{Mg}$	$16.0 \times 10^6/\text{ton}$
Wood	$1.47 \times 10^6/\text{m}^3$	$21.0 \times 10^6/\text{cord}$
Liquid fuels		
Residual fuel oil	$10 \times 10^3/\text{liter}$	$6.3 \times 10^6/\text{bbl}$
Distillate fuel oil	$9.35 \times 10^3/\text{liter}$	$5.9 \times 10^6/\text{bbl}$
Gaseous fuels		
Natural gas	$9,350/\text{m}^3$	$1,050/\text{ft}^3$
Liquefied petroleum gas		
Butane	$6,480/\text{liter}$	$97,400/\text{gal}$
Propane	$6,030/\text{liter}$	$90,500/\text{gal}$

WEIGHTS OF SELECTED SUBSTANCES

Type Of Substance	g/liter	lb/gal
Asphalt	1030	8.57
Butane, liquid at 60°F	579	4.84
Crude oil	850	7.08
Distillate oil	845	7.05
Gasoline	739	6.17
Propane, liquid at 60°F	507	4.24
Residual oil	944	7.88
Water	1000	8.4

DENSITIES OF SELECTED SUBSTANCES

Substance	Density	
Fuels		
Crude Oil	874 kg/m ³	7.3 lb/gal
Residual Oil	944 kg/m ³	7.88 lb/gal
Distillate Oil	845 kg/m ³	7.05 lb/gal
Gasoline	739 kg/m ³	6.17 lb/gal
Natural Gas	673 kg/m ³	1 lb/23.8 ft ³
Butane	579 kg/m ³	4.84 lb/gal (liquid)
Propane	507 kg/m ³	4.24 lb/gal (liquid)
Wood (Air dried)		
Elm	561 kg/m ³	35 lb/ft ³
Fir, Douglas	513 kg/m ³	32 lb/ft ³
Fir, Balsam	400 kg/m ³	25 lb/ft ³
Hemlock	465 kg/m ³	29 lb/ft ³
Hickory	769 kg/m ³	48 lb/ft ³
Maple, Sugar	689 kg/m ³	43 lb/ft ³
Maple, White	529 kg/m ³	33 lb/ft ³
Oak, Red	673 kg/m ³	42 lb/ft ³
Oak, White	769 kg/m ³	48 lb/ft ³
Pine, Southern	641 kg/m ³	40 lb/ft ³
Agricultural Products		
Corn	25.4 kg/bu	56 lb/bu
Milo	25.4 kg/bu	56 lb/bu
Oats	14.5 kg/bu	32 lb/bu
Barley	21.8 kg/bu	48 lb/bu
Wheat	27.2 kg/bu	60 lb/bu
Cotton	226 kg/bale	500 lb/bale
Mineral Products		
Brick	2.95 kg/brick	6.5 lb/brick
Cement	170 kg/bbl	375 lb/bbl
Cement	1483 kg/m ³	2500 lb/yd ³

DENSITIES OF SELECTED SUBSTANCES (cont.).

Substance	Density	
Concrete	2373 kg/m ³	4000 lb/yd ³
Glass, Common	2595 kg/m ³	162 lb/ft ³
Gravel, Dry Packed	1600 - 1920 kg/m ³	100 - 120 lb/ft ³
Gravel, Wet	2020 kg/m ³	126 lb/ft ³
Gypsum, Calcined	880 - 960 kg/m ³	55 - 60 lb/ft ³
Lime, Pebble	850 - 1025 kg/m ³	53 - 64 lb/ft ³
Sand, Gravel (Dry, loose)	1440 - 1680 kg/m ³	90 - 105 lb/ft ³

CONVERSION FACTORS

The table of conversion factors on the following pages contains factors for converting English to metric units and metric to English units as well as factors to manipulate units within the same system. The factors are arranged alphabetically by unit within the following property groups.

- Area
- Density
- Energy
- Force
- Length
- Mass
- Pressure
- Velocity
- Volume
- Volumetric Rate

To convert a number from one unit to another:

1. Locate the unit in which the number is currently expressed in the left-hand column of the table;
2. Find the desired unit in the center column; and
3. Multiply the number by the corresponding conversion factor in the right-hand column.

CONVERSION FACTORS^a

To Convert From	To	Multiply By
Area		
Acres	Sq feet	4.356×10^4
Acres	Sq kilometers	4.0469×10^{-3}
Acres	Sq meters	4.0469×10^3
Acres	Sq miles (statute)	1.5625×10^{-3}
Acres	Sq yards	4.84×10^3
Sq feet	Acres	2.2957×10^{-5}
Sq feet	Sq cm	929.03
Sq feet	Sq inches	144.0
Sq feet	Sq meters	0.092903
Sq feet	Sq miles	3.587×10^{-8}
Sq feet	Sq yards	0.111111
Sq inches	Sq feet	6.9444×10^{-3}
Sq inches	Sq meters	6.4516×10^{-4}
Sq inches	Sq mm	645.16
Sq kilometers	Acres	247.1
Sq kilometers	Sq feet	1.0764×10^7
Sq kilometers	Sq meters	1.0×10^6
Sq kilometers	Sq miles	0.386102
Sq kilometers	Sq yards	1.196×10^6
Sq meters	Sq cm	1.0×10^4
Sq meters	Sq feet	10.764
Sq meters	Sq inches	1.55×10^3
Sq meters	Sq kilometers	1.0×10^{-6}
Sq meters	Sq miles	3.861×10^{-7}
Sq meters	Sq mm	1.0×10^6
Sq meters	Sq yards	1.196
Sq miles	Acres	640.0
Sq miles	Sq feet	2.7878×10^7
Sq miles	Sq kilometers	2.590

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Sq miles	Sq meters	2.59×10^6
Sq miles	Sq yards	3.0976×10^6
Sq yards	Acres	2.0661×10^{-4}
Sq yards	Sq cm	8.3613×10^3
Sq yards	Sq ft	9.0
Sq yards	Sq inches	1.296×10^3
Sq yards	Sq meters	0.83613
Sq yards	Sq miles	3.2283×10^{-7}
Density		
Dynes/cu cm	Grams/cu cm	1.0197×10^{-3}
Grains/cu foot	Grams/cu meter	2.28835
Grams/cu cm	Dynes/cu cm	980.665
Grams/cu cm	Grains/milliliter	15.433
Grams/cu cm	Grams/milliliter	1.0
Grams/cu cm	Pounds/cu inch	1.162
Grams/cu cm	Pounds/cu foot	62.428
Grams/cu cm	Pounds/cu inch	0.036127
Grams/cu cm	Pounds/gal (Brit.)	10.022
Grams/cu cm	Pounds/gal (U. S., dry)	9.7111
Grams/cu cm	Pounds/gal (U. S., liq.)	8.3454
Grams/cu meter	Grains/cu foot	0.4370
Grams/liter	Pounds/gal (U. S.)	8.345×10^{-3}
Kilograms/cu meter	Grams/cu cm	0.001
Kilograms/cu meter	Pounds/cu ft	0.0624
Kilograms/cu meter	Pounds/cu in	3.613×10^{-5}
Pounds/cu foot	Grams/cu cm	0.016018
Pounds/cu foot	kg/cu meter	16.018
Pounds/cu inch	Grams/cu cm	27.68
Pounds/cu inch	Grams/liter	27.681
Pounds/cu inch	kg/cu meter	2.768×10^4

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Pounds/gal (U. S., liq.)	Grams/cu cm	0.1198
Pounds/gal (U. S., liq.)	Pounds/cu ft	7.4805
Energy		
Btu	Cal. gm (IST.)	251.83
Btu	Ergs	1.05435×10^{10}
Btu	Foot-pounds	777.65
Btu	Hp-hours	3.9275×10^{-4}
Btu	Joules (Int.)	1054.2
Btu	kg-meters	107.51
Btu	kW-hours (Int.)	2.9283×10^{-4}
Btu/hr	Cal. kg/hr	0.252
Btu/hr	Ergs/sec	2.929×10^6
Btu/hr	Foot-pounds/hr	777.65
Btu/hr	Horsepower (mechanical)	3.9275×10^{-4}
Btu/hr	Horsepower (boiler)	2.9856×10^{-5}
Btu/hr	Horsepower (electric)	3.926×10^{-4}
Btu/hr	Horsepower (metric)	3.982×10^{-4}
Btu/hr	Kilowatts	2.929×10^{-4}
Btu/lb	Foot-pounds/lb	777.65
Btu/lb	Hp-hr/lb	3.9275×10^{-4}
Btu/lb	Joules/gram	2.3244
Calories, kg (mean)	Btu (IST.)	3.9714
Calories, kg (mean)	Ergs	4.190×10^{10}
Calories, kg (mean)	Foot-pounds	3.0904×10^3
Calories, kg (mean)	Hp-hours	1.561×10^{-3}
Calories, kg (mean)	Joules	4.190×10^3
Calories, kg (mean)	kg-meters	427.26
Calories, kg (mean)	kW-hours (Int.)	1.1637×10^{-3}
Ergs	Btu	9.4845×10^{-11}
Ergs	Foot-poundals	2.373×10^{-6}

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Ergs	Foot-pounds	7.3756×10^{-8}
Ergs	Joules (Int.)	9.99835×10^{-8}
Ergs	kW-hours	2.7778×10^{-14}
Ergs	kg-meters	1.0197×10^{-8}
Foot-pounds	Btu (IST.)	1.2851×10^{-3}
Foot-pounds	Cal. kg (IST.)	3.2384×10^{-4}
Foot-pounds	Ergs	1.3558×10^7
Foot-pounds	Foot-poundals	32.174
Foot-pounds	Hp-hours	5.0505×10^{-7}
Foot-pounds	Joules	1.3558
Foot-pounds	kg-meters	0.138255
Foot-pounds	kW-hours (Int.)	3.76554×10^{-7}
Foot-pounds	Newton-meters	1.3558
Foot-pounds/hr	Btu/min	2.1432×10^{-5}
Foot-pounds/hr	Ergs/min	2.2597×10^5
Foot-pounds/hr	Horsepower (mechanical)	5.0505×10^{-7}
Foot-pounds/hr	Horsepower (metric)	5.121×10^{-7}
Foot-pounds/hr	Kilowatts	3.766×10^{-7}
Horsepower (mechanical)	Btu (mean)/hr	2.5425×10^3
Horsepower (mechanical)	Ergs/sec	7.457×10^9
Horsepower (mechanical)	Foot-pounds/hr	1.980×10^6
Horsepower (mechanical)	Horsepower (boiler)	0.07602
Horsepower (mechanical)	Horsepower (electric)	0.9996
Horsepower (mechanical)	Horsepower (metric)	1.0139
Horsepower (mechanical)	Joules/sec	745.70
Horsepower (mechanical)	Kilowatts (Int.)	0.74558
Horsepower (boiler)	Btu (mean)/hr	3.3446×10^4
Horsepower (boiler)	Ergs/sec	9.8095×10^{10}
Horsepower (boiler)	Foot-pounds/min	4.341×10^5
Horsepower (boiler)	Horsepower (mechanical)	13.155

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Horsepower (boiler)	Horsepower (electric)	13.15
Horsepower (boiler)	Horsepower (metric)	13.337
Horsepower (boiler)	Joules/sec	9.8095×10^3
Horsepower (boiler)	Kilowatts	9.8095
Horsepower (electric)	Btu (mean)/hr	2.5435×10^3
Horsepower (electric)	Cal. kg/hr	641.87
Horsepower (electric)	Ergs/sec	7.46×10^9
Horsepower (electric)	Foot-pounds/min	3.3013×10^4
Horsepower (electric)	Horsepower (boiler)	0.07605
Horsepower (electric)	Horsepower (metric)	1.0143
Horsepower (electric)	Joules/sec	746.0
Horsepower (electric)	Kilowatts	0.746
Horsepower (metric)	Btu (mean)/hr	2.5077×10^3
Horsepower (metric)	Ergs/sec	7.355×10^9
Horsepower (metric)	Foot-pounds/min	3.255×10^4
Horsepower (metric)	Horsepower (mechanical)	0.98632
Horsepower (metric)	Horsepower (boiler)	0.07498
Horsepower (metric)	Horsepower (electric)	0.9859
Horsepower (metric)	kg-meters/sec	75.0
Horsepower (metric)	Kilowatts	0.7355
Horsepower-hours	Btu (mean)	2.5425×10^3
Horsepower-hours	Foot-pounds	1.98×10^6
Horsepower-hours	Joules	2.6845×10^6
Horsepower-hours	kg-meters	2.73745×10^5
Horsepower-hours	kW-hours	0.7457
Joules (Int.)	Btu (IST.)	9.4799×10^{-4}
Joules (Int.)	Ergs	1.0002×10^7
Joules (Int.)	Foot-poundals	12.734
Joules (Int.)	Foot-pounds	0.73768
Joules (Int.)	kW-hours	2.778×10^{-7}

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Joules (Int.)/sec	Btu (mean)/min	0.05683
Joules (Int.)/sec	Cal. kg/min	0.01434
Joules (Int.)/sec	Horsepower	1.341×10^{-3}
Kilogram-meters	Btu (mean)	9.2878×10^{-3}
Kilogram-meters	Cal. kg (mean)	2.3405×10^{-3}
Kilogram-meters	Ergs	9.80665×10^7
Kilogram-meters	Foot-poundals	232.715
Kilogram-meters	Foot-pounds	7.233
Kilogram-meters	Hp-hours	3.653×10^{-6}
Kilogram-meters	Joules (Int.)	9.805
Kilogram-meters	kW-hours	2.724×10^{-6}
Kilogram-meters/sec	Watts	9.80665
Kilowatts (Int.)	Btu (IST.)/hr	3.413×10^3
Kilowatts (Int.)	Cal. kg (IST.)/hr	860.0
Kilowatts (Int.)	Ergs/sec	1.0002×10^{10}
Kilowatts (Int.)	Foot-poundals/min	1.424×10^6
Kilowatts (Int.)	Foot-pounds/min	4.4261×10^4
Kilowatts (Int.)	Horsepower (mechanical)	1.341
Kilowatts (Int.)	Horsepower (boiler)	0.10196
Kilowatts (Int.)	Horsepower (electric)	1.3407
Kilowatts (Int.)	Horsepower (metric)	1.3599
Kilowatts (Int.)	Joules (Int.)/hr	3.6×10^6
Kilowatts (Int.)	kg-meters/hr	3.6716×10^5
Kilowatt-hours (Int.)	Btu (mean)	3.41×10^3
Kilowatt-hours (Int.)	Foot-pounds	2.6557×10^6
Kilowatt-hours (Int.)	Hp-hours	1.341
Kilowatt-hours (Int.)	Joules (Int.)	3.6×10^6
Kilowatt-hours (Int.)	kg-meters	3.6716×10^5
Newton-meters	Gram-cm	1.01972×10^4
Newton-meters	kg-meters	0.101972

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Newton-meters	Pound-feet	0.73756
Force		
Dynes	Newtons	1.0×10^{-5}
Dynes	Poundals	7.233×10^{-5}
Dynes	Pounds	2.248×10^{-6}
Newtons	Dynes	1.0×10^{-5}
Newtons	Pounds (avdp.)	0.22481
Poundals	Dynes	1.383×10^4
Poundals	Newtons	0.1383
Poundals	Pounds (avdp.)	0.03108
Pounds (avdp.)	Dynes	4.448×10^5
Pounds (avdp.)	Newtons	4.448
Pounds (avdp.)	Poundals	32.174
Length		
Feet	Centimeters	30.48
Feet	Inches	12
Feet	Kilometers	3.048×10^{-4}
Feet	Meters	0.3048
Feet	Miles (statute)	1.894×10^{-4}
Inches	Centimeters	2.540
Inches	Feet	0.08333
Inches	Kilometers	2.54×10^{-5}
Inches	Meters	0.0254
Kilometers	Feet	3.2808×10^3
Kilometers	Meters	1000
Kilometers	Miles (statute)	0.62137
Kilometers	Yards	1.0936×10^3
Meters	Feet	3.2808
Meters	Inches	39.370
Micrometers	Angstrom units	1.0×10^4

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Micrometers	Centimeters	1.0×10^{-3}
Micrometers	Feet	3.2808×10^{-6}
Micrometers	Inches	3.9370×10^{-5}
Micrometers	Meters	1.0×10^{-6}
Micrometers	Millimeters	0.001
Micrometers	Nanometers	1000
Miles (statute)	Feet	5280
Miles (statute)	Kilometers	1.6093
Miles (statute)	Meters	1.6093×10^3
Miles (statute)	Yards	1760
Millimeters	Angstrom units	1.0×10^7
Millimeters	Centimeters	0.1
Millimeters	Inches	0.03937
Millimeters	Meters	0.001
Millimeters	Micrometers	1000
Millimeters	Mils	39.37
Nanometers	Angstrom units	10
Nanometers	Centimeters	1.0×10^{-7}
Nanometers	Inches	3.937×10^{-8}
Nanometers	Micrometers	0.001
Nanometers	Millimeters	1.0×10^{-6}
Yards	Centimeters	91.44
Yards	Meters	0.9144
Mass		
Grains	Grams	0.064799
Grains	Milligrams	64.799
Grains	Pounds (apoth. or troy)	1.7361×10^{-4}
Grains	Pounds (avdp.)	1.4286×10^{-4}
Grains	Tons (metric)	6.4799×10^{-8}
Grams	Dynes	980.67

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Grams	Grains	15.432
Grams	Kilograms	0.001
Grams	Micrograms	1×10^6
Grams	Pounds (avdp.)	2.205×10^{-3}
Grams	Tons, metric (megagrams)	1×10^{-6}
Kilograms	Grains	1.5432×10^4
Kilograms	Poundals	70.932
Kilograms	Pounds (apoth. or troy)	2.679
Kilograms	Pounds (avdp.)	2.2046
Kilograms	Tons (long)	9.842×10^{-4}
Kilograms	Tons (metric)	0.001
Kilograms	Tons (short)	1.1023×10^{-3}
Megagrams	Tons (metric)	1.0
Milligrams	Grains	0.01543
Milligrams	Grams	1.0×10^{-3}
Milligrams	Ounces (apoth. or troy)	3.215×10^{-5}
Milligrams	Ounces (avdp.)	3.527×10^{-5}
Milligrams	Pounds (apoth. or troy)	2.679×10^{-6}
Milligrams	Pounds (avdp.)	2.2046×10^{-6}
Ounces (apoth. or troy)	Grains	480
Ounces (apoth. or troy)	Grams	31.103
Ounces (apoth. or troy)	Ounces (avdp.)	1.097
Ounces (avdp.)	Grains	437.5
Ounces (avdp.)	Grams	28.350
Ounces (avdp.)	Ounces (apoth. or troy)	0.9115
Ounces (avdp.)	Pounds (apoth. or troy)	0.075955
Ounces (avdp.)	Pounds (avdp.)	0.0625
Pounds (avdp.)	Poundals	32.174
Pounds (avdp.)	Pounds (apoth. or troy)	1.2153
Pounds (avdp.)	Tons (long)	4.4643×10^{-4}

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Pounds (avdp.)	Tons (metric)	4.5359×10^{-4}
Pounds (avdp.)	Tons (short)	5.0×10^{-4}
Pounds (avdp.)	Grains	7000
Pounds (avdp.)	Grams	453.59
Pounds (avdp.)	Ounces (apoth. or troy)	14.583
Pounds (avdp.)	Ounces (avdp.)	16
Tons (long)	Kilograms	1.016×10^3
Tons (long)	Pounds (apoth. or troy)	2.722×10^3
Tons (long)	Pounds (avdp.)	2.240×10^3
Tons (long)	Tons (metric)	1.016
Tons (long)	Tons (short)	1.12
Tons (metric)	Grams	1.0×10^6
Tons (metric)	Megagrams	1.0
Tons (metric)	Pounds (apoth. or troy)	2.6792×10^3
Tons (metric)	Pounds (avdp.)	2.2046×10^3
Tons (metric)	Tons (long)	0.9842
Tons (metric)	Tons (short)	1.1023
Tons (short)	Kilograms	907.18
Tons (short)	Pounds (apoth. or troy)	2.4301×10^3
Tons (short)	Pounds (avdp.)	2000
Tons (short)	Tons (long)	0.8929
Tons (short)	Tons (metric)	0.9072
Pressure		
Atmospheres	cm of H ₂ O (4°C)	1.033×10^3
Atmospheres	Ft of H ₂ O (39.2°F)	33.8995
Atmospheres	In. of Hg (32°F)	29.9213
Atmospheres	kg/sq cm	1.033
Atmospheres	mm of Hg (0°C)	760
Atmospheres	Pounds/sq inch	14.696
Inches of Hg (60°F)	Atmospheres	0.03333

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Inches of Hg (60°F)	Grams/sq cm	34.434
Inches of Hg (60°F)	mm of Hg (60°F)	25.4
Inches of Hg (60°F)	Pounds/sq ft	70.527
Inches of H ₂ O (4°C)	Atmospheres	2.458×10^{-3}
Inches of H ₂ O (4°C)	In. of Hg (32°F)	0.07355
Inches of H ₂ O (4°C)	kg/sq meter	25.399
Inches of H ₂ O (4°C)	Pounds/sq ft	5.2022
Inches of H ₂ O (4°C)	Pounds/sq inch	0.036126
Kilograms/sq cm	Atmospheres	0.96784
Kilograms/sq cm	cm of Hg (0°C)	73.556
Kilograms/sq cm	Ft of H ₂ O (39.2°F)	32.809
Kilograms/sq cm	In. of Hg (32°F)	28.959
Kilograms/sq cm	Pounds/sq inch	14.223
Millimeters of Hg (0°C)	Atmospheres	1.3158×10^{-3}
Millimeters of Hg (0°C)	Grams/sq cm	1.3595
Millimeters of Hg (0°C)	Pounds/sq inch	0.019337
Pounds/sq inch	Atmospheres	0.06805
Pounds/sq inch	cm of Hg (0°C)	5.1715
Pounds/sq inch	cm of H ₂ O (4°C)	70.309
Pounds/sq inch	In. of Hg (32°F)	2.036
Pounds/sq inch	In. of H ₂ O (39.2°F)	27.681
Pounds/sq inch	kg/sq cm	0.07031
Pounds/sq inch	mm of Hg (0°C)	51.715
Velocity		
Centimeters/sec	Feet/min	1.9685
Centimeters/sec	Feet/sec	0.0328
Centimeters/sec	Kilometers/hr	0.036
Centimeters/sec	Meters/min	0.6
Centimeters/sec	Miles/hr	0.02237

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Feet/minute	cm/sec	0.508
Feet/minute	Kilometers/hr	0.01829
Feet/minute	Meters/min	0.3048
Feet/minute	Meters/sec	5.08×10^{-3}
Feet/minute	Miles/hr	0.01136
Feet/sec	cm/sec	30.48
Feet/sec	Kilometers/hr	1.0973
Feet/sec	Meters/min	18.288
Feet/sec	Miles/hr	0.6818
Kilometers/hr	cm/sec	27.778
Kilometers/hr	Feet/hr	3.2808×10^3
Kilometers/hr	Feet/min	54.681
Kilometers/hr	Meters/sec	0.27778
Kilometers/hr	Miles (statute)/hr	0.62137
Meters/min	cm/sec	1.6667
Meters/min	Feet/min	3.2808
Meters/min	Feet/sec	0.05468
Meters/min	Kilometers/hr	0.06
Miles/hr	cm/sec	44.704
Miles/hr	Feet/hr	5280
Miles/hr	Feet/min	88
Miles/hr	Feet/sec	1.4667
Miles/hr	Kilometers/hr	1.6093
Miles/hr	Meters/min	26.822
Volume		
Barrels (petroleum, U. S.)	Cu feet	5.6146
Barrels (petroleum, U. S.)	Gallons (U. S.)	42
Barrels (petroleum, U. S.)	Liters	158.98
Barrels (U. S., liq.)	Cu feet	4.2109
Barrels (U. S., liq.)	Cu inches	7.2765×10^3

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Barrels (U. S., liq.)	Cu meters	0.1192
Barrels (U. S., liq.)	Gallons (U. S., liq.)	31.5
Barrels (U. S., liq.)	Liters	119.24
Cubic centimeters	Cu feet	3.5315×10^{-5}
Cubic centimeters	Cu inches	0.06102
Cubic centimeters	Cu meters	1.0×10^{-6}
Cubic centimeters	Cu yards	1.308×10^{-6}
Cubic centimeters	Gallons (U. S., liq.)	2.642×10^{-4}
Cubic centimeters	Quarts (U. S., liq.)	1.0567×10^{-3}
Cubic feet	Cu centimeters	2.8317×10^4
Cubic feet	Cu meters	0.028317
Cubic feet	Gallons (U. S., liq.)	7.4805
Cubic feet	Liters	28.317
Cubic inches	Cu cm	16.387
Cubic inches	Cu feet	5.787×10^{-4}
Cubic inches	Cu meters	1.6387×10^{-5}
Cubic inches	Cu yards	2.1433×10^{-5}
Cubic inches	Gallons (U. S., liq.)	4.329×10^{-3}
Cubic inches	Liters	0.01639
Cubic inches	Quarts (U. S., liq.)	0.01732
Cubic meters	Barrels (U. S., liq.)	8.3864
Cubic meters	Cu cm	1.0×10^6
Cubic meters	Cu feet	35.315
Cubic meters	Cu inches	6.1024×10^4
Cubic meters	Cu yards	1.308
Cubic meters	Gallons (U. S., liq.)	264.17
Cubic meters	Liters	1000
Cubic yards	Bushels (Brit.)	21.022
Cubic yards	Bushels (U. S.)	21.696
Cubic yards	Cu cm	7.6455×10^5

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Cubic yards	Cu feet	27
Cubic yards	Cu inches	4.6656×10^4
Cubic yards	Cu meters	0.76455
Cubic yards	Gallons	168.18
Cubic yards	Gallons	173.57
Cubic yards	Gallons	201.97
Cubic yards	Liters	764.55
Cubic yards	Quarts	672.71
Cubic yards	Quarts	694.28
Cubic yards	Quarts	807.90
Gallons (U. S., liq.)	Barrels (U. S., liq.)	0.03175
Gallons (U. S., liq.)	Barrels (petroleum, U. S.)	0.02381
Gallons (U. S., liq.)	Bushels (U. S.)	0.10742
Gallons (U. S., liq.)	Cu centimeters	3.7854×10^3
Gallons (U. S., liq.)	Cu feet	0.13368
Gallons (U. S., liq.)	Cu inches	231
Gallons (U. S., liq.)	Cu meters	3.7854×10^{-3}
Gallons (U. S., liq.)	Cu yards	4.951×10^{-3}
Gallons (U. S., liq.)	Gallons (wine)	1.0
Gallons (U. S., liq.)	Liters	3.7854
Gallons (U. S., liq.)	Ounces (U. S., fluid)	128.0
Gallons (U. S., liq.)	Pints (U. S., liq.)	8.0
Gallons (U. S., liq.)	Quarts (U. S., liq.)	4.0
Liters	Cu centimeters	1000
Liters	Cu feet	0.035315
Liters	Cu inches	61.024
Liters	Cu meters	0.001
Liters	Gallons (U. S., liq.)	0.2642
Liters	Ounces (U. S., fluid)	33.814

CONVERSION FACTORS (cont.).

To Convert From	To	Multiply By
Volumetric Rate		
Cu ft/min	Cu cm/sec	471.95
Cu ft/min	Cu ft /hr	60. 0
Cu ft/min	Gal (U. S.)/min	7.4805
Cu ft/min	Liters/sec	0.47193
Cu meters/min	Gal (U. S.)/min	264.17
Cu meters/min	Liters/min	999.97
Gallons (U. S.)/hr	Cu ft/hr	0.13368
Gallons (U. S.)/hr	Cu meters/min	6.309×10^{-5}
Gallons (U. S.)/hr	Cu yd/min	8.2519×10^{-5}
Gallons (U. S.)/hr	Liters/hr	3.7854
Liters/min	Cu ft/min	0.0353
Liters/min	Gal (U. S., liq.)/min	0.2642

^a Where appropriate, the conversion factors appearing in this table have been rounded to four to six significant figures for ease in use. The accuracy of these numbers is considered suitable for use with emissions data; if a more accurate number is required, tables containing exact factors should be consulted.

CONVERSION FACTORS FOR COMMON AIR POLLUTION MEASUREMENTS

AIRBORNE PARTICULATE MATTER

To Convert From	To	Multiply By
Milligrams/cu m	Grams/cu ft	283.2×10^{-6}
	Grams/cu m	0.001
	Micrograms/cu m	1000.0
	Micrograms/cu ft	28.32
	Pounds/1000 cu ft	62.43×10^{-6}
Grams/cu ft	Milligrams/cu m	35.3145×10^3
	Grams/cu m	35.314
	Micrograms/cu m	35.314×10^6
	Micrograms/cu ft	1.0×10^6
	Pounds/1000 cu ft	2.2046
Grams/cu m	Milligrams/cu m	1000.0
	Grams/cu ft	0.02832
	Micrograms/cu m	1.0×10^6
	Micrograms/cu ft	28.317×10^3
	Pounds/1000 cu ft	0.06243
Micrograms/cu m	Milligrams/cu m	0.001
	Grams/cu ft	28.317×10^{-9}
	Grams/cu m	1.0×10^{-6}
	Micrograms/cu ft	0.02832
	Pounds/1000 cu ft	62.43×10^{-9}
Micrograms/cu ft	Milligrams/cu m	35.314×10^{-3}
	Grams/cu ft	1.0×10^{-6}
	Grams/cu m	35.314×10^{-6}
	Micrograms/cu m	35.314
	Pounds/1000 cu ft	2.2046×10^{-6}
Pounds/1000 cu ft	Milligrams/cu m	16.018×10^3
	Grams/cu ft	0.35314
	Micrograms/cu m	16.018×10^6
	Grams/cu m	16.018
	Micrograms/cu ft	353.14×10^3

CONVERSION FACTORS FOR COMMON AIR POLLUTION MEASUREMENTS (cont.).

SAMPLING PRESSURE

To Convert From	To	Multiply By
Millimeters of mercury (0°C)	Inches of water (60°F)	0.5358
Inches of mercury (0°C)	Inches of water (60°F)	13.609
	Millimeters of mercury (0°C)	1.8663
Inches of water (60°F)	Inches of mercury (0°C)	73.48×10^{-3}

CONVERSION FACTORS FOR COMMON AIR POLLUTION MEASUREMENTS (cont.).

ATMOSPHERIC GASES

To Convert From	To	Multiply By
Milligrams/cu m	Micrograms/cu m	1000.0
	Micrograms/liter	1.0
	ppm by volume (20°C)	24.04/M
	ppm by weight	0.8347
	Pounds/cu ft	62.43×10^{-9}
Micrograms/cu m	Milligrams/cu m	0.001
	Micrograms/liter	0.001
	ppm by volume (20°C)	0.02404/M
	ppm by weight	834.7×10^{-6}
	Pounds/cu ft	62.43×10^{-12}
Micrograms/liter	Milligrams/cu m	1.0
	Micrograms/cu m	1000.0
	ppm by volume (20°C)	24.04/M
	ppm by weight	0.8347
	Pounds/cu ft	62.43×10^{-9}
ppm by volume (20°C)	Milligrams/cu m	M/24.04
	Micrograms/cu m	M/0.02404
	Micrograms/liter	M/24.04
	ppm by weight	M/28.8
	Pounds/cu ft	$M/385.1 \times 10^6$
ppm by weight	Milligrams/cu m	1.198
	Micrograms/cu m	1.198×10^{-3}
	Micrograms/liter	1.198
	ppm by volume (20°C)	28.8/M
	Pounds/cu ft	7.48×10^{-6}
Pounds/cu ft	Milligrams/cu m	16.018×10^6
	Micrograms/cu m	16.018×10^9
	Micrograms/liter	16.018×10^6
	ppm by volume (20°C)	$385.1 \times 10^6/M$
	ppm by weight	133.7×10^3

M = Molecular weight of gas.

CONVERSION FACTORS FOR COMMON AIR POLLUTION MEASUREMENTS (cont.).

VELOCITY

To Convert From	To	Multiply By
Meters/sec	Kilometers/hr	3.6
	Feet/sec	3.281
	Miles/hr	2.237
Kilometers/hr	Meters/sec	0.2778
	Feet/sec	0.9113
	Miles/hr	0.6214
Feet/sec	Meters/sec	0.3048
	Kilometers/hr	1.09728
	Miles/hr	0.6818
Miles/hr	Meters/sec	0.4470
	Kilometers/hr	1.6093
	Feet/sec	1.4667

ATMOSPHERIC PRESSURE

To Convert From	To	Multiply By
Atmospheres	Millimeters of mercury	760.0
	Inches of mercury	29.92
	Millibars	1013.2
Millimeters of mercury	Atmospheres	1.316×10^{-3}
	Inches of mercury	39.37×10^{-3}
	Millibars	1.333
Inches of mercury	Atmospheres	0.03333
	Millimeters of mercury	25.4005
	Millibars	33.35
Millibars	Atmospheres	0.00987
	Millimeters of mercury	0.75
	Inches of mercury	0.30

VOLUME EMISSIONS

To Convert From	To	Multiply By
Cubic m/min	Cubic ft/min	35.314
Cubic ft/min	Cubic m/min	0.0283

BOILER CONVERSION FACTORS

1 Megawatt	=	10.5 x 10 ⁶ Btu/hr (8 to 14 x 10 ⁶ Btu/hr)	NOTES: In the relationships,
1 Megawatt	=	8 x 10 ³ lb steam/hr (6 to 11 x 10 ³ lb steam/hr)	Megawatt is the net electric production of a steam electric power plant.
1 BHP	=	34.5 lb steam/hr	BHP is boiler horsepower.
1 BHP	=	45 x 10 ³ Btu/hr (40 to 50 x 10 ³ Btu/hr)	lb steam/hr is the steam production rate of the boiler.
1 lb steam/hr	=	1.4 x 10 ³ Btu/hr (1.2 to 1.7 x 10 ³ Btu/hr)	Btu/hr is the heat input rate to the boiler (based on the gross or high heating value of the fuel burned).

For less efficient (generally older and/or smaller) boiler operations, use the higher values expressed. For more efficient operations (generally newer and/or larger), use the lower values.

Volume	cu in	ml	liters	ounces (U. S. fl.)	gallons (U. S.)	barrels (U. S.)	cu ft
Cubic inches		16.3868	0.0163868	0.5541	4.3290x10 ⁻³	1.37429x10 ⁻⁴	5.78704x10 ⁻⁴
Milliliters	0.061024		0.001	0.03381	2.6418x10 ⁻⁴	8.387x10 ⁻⁶	3.5316x10 ⁻⁵
Liters	61.024	1000		33.8147	0.26418	8.387x10 ⁻³	0.035316
Ounces (U. S. fl.)	1.80469	29.5729	0.029573		7.8125x10 ⁻³	2.48x10 ⁻⁴	1.0443x10 ⁻³
Gallons (U. S.) ^a	231	3785.3	3.7853	128		0.031746	0.13368
Barrels (U. S.)	7276.5	1.1924x10 ⁵	119.2369	4032.0	31.5		4.2109
Cubic feet	1728	2.8316x10 ⁴	28.316	957.568	7.481	0.23743	

^a U. S. gallon of water at 16.7°C (62°F) weighs 3.780 kg or 8.337 pounds (avoir.)

Mass	grams	kilograms	ounces (avoir.)	pounds (avoir.)	grains	tons (U. S.)	milligrams
Grams		0.001	3.527x10 ⁻²	2.205x10 ⁻³	15.432	1.102x10 ⁻⁶	1000
Kilograms	1000		35.274	2.2046	15432	1.102x10 ⁻³	1x10 ⁶
Ounces (avoir.)	28.350	0.028350		0.0625	437.5	3.125x10 ⁻⁵	2.8350x10 ⁴
Pounds (avoir.) ^a	453.59	0.45359	16.0		7000	5.0x10 ⁻⁴	4.5359x10 ⁵
Grains	0.06480	6.480x10 ⁻⁵	2.286x10 ⁻³	1.429x10 ⁻⁴		7.142x10 ⁻⁸	64.799
Tons (U. S.)	9.072x10 ⁵	907.19	3.200x10 ⁴	2000	1.4x10 ⁷		9.0718x10 ⁸
Milligrams	0.001	1x10 ⁻⁶	3.527x10 ⁻⁵	2.205x10 ⁻⁶	0.015432	1.102x10 ⁻⁹	

^a Mass of 27.692 cubic inches water weighed in air at 4.0°C, 760 mm mercury pressure.

Work and Energy	g cal.	kg cal.	ergs	joules	Btu	ft lb	kg meters	L-Atm	HP hours	ft poundals	kWh	Wh
Gram calories (mean)		0.001	4.186x10 ⁷	4.186	3.9680x10 ⁻³	3.0874	0.42685	0.041311	1.5593x10 ⁻⁶	99.334	1.1628x10 ⁻⁶	1.1628x10 ⁻³
Kilogram calories	1000		4.186x10 ¹⁰	4186	3.9680	3087.4	426.85	41.311	1.5593x10 ⁻³	99334	1.1628x10 ⁻³	1.1628
Ergs	2.3889x10 ⁻⁸	2.3889x10 ⁻¹¹		1x10 ⁻⁷	9.4805x10 ⁻¹¹	7.3756x10 ⁻⁸	1.0197x10 ⁻⁸	9.8689x10 ⁻¹⁰	3.7251x10 ⁻¹⁴	2.3730x10 ⁻⁶	2.7778x10 ⁻¹⁴	2.7778x10 ⁻¹¹
Joules	0.23889	2.3889x10 ⁻⁴	1x10 ⁷		9.4805x10 ⁻⁴	0.73756	0.10197	9.8689x10 ⁻³	3.7251x10 ⁻⁷	23.730	2.7778x10 ⁻⁷	2.7778x10 ⁻⁴
Btu (mean)	251.98	0.25198	1.0548x10 ¹⁰	1054.8		777.98	107.56	10.409	3.9292x10 ⁻⁴	2.5030x10 ⁴	2.930x10 ⁻⁴	0.2930
Foot pounds	0.32389	3.2389x10 ⁻⁴	1.35582x10 ⁷	1.3558	1.2854x10 ⁻³		0.13825	0.013381	5.0505x10 ⁻⁷	32.174	3.7662x10 ⁻⁷	3.7662x10 ⁻⁴
Kilogram meters	2.3427	2.3427x10 ⁻³	9.8066x10 ⁷	9.8066	9.2967x10 ⁻³	7.2330		0.096781	3.6529x10 ⁻⁶	232.71	2.7241x10 ⁻⁶	2.7241x10 ⁻³
Liter atmospheres (normal)	24.206	2.4206x10 ⁻²	1.0133x10 ⁹	101.328	0.09606	74.735	10.333		3.7745x10 ⁻⁵	2404.5	2.8164x10 ⁻⁵	2.8164x10 ⁻²
Horsepower hours	6.4130x10 ⁵	641.30	2.6845x10 ¹³	2.6845x10 ⁶	2454.0	1.9800x10 ⁶	2.7374x10 ⁵	26494		6.3705x10 ⁷	0.7457	745.7
Foot poundals	0.010067	10.067x10 ⁻⁶	4.21402x10 ⁵	0.04214	3.9952x10 ⁻⁵	0.031081	4.2972x10 ⁻³	4.1558x10 ⁻⁴	1.5697x10 ⁻⁸		1.17055x10 ⁻⁸	1.17055x10 ⁻⁵
Kilowatt hours	8.6001x10 ⁵	860.01	3.6000x10 ¹³	3.6000x10 ⁶	3413.0	2.6552x10 ⁶	3.6709x10 ⁻⁵	3.5529x10 ⁶	1.3440	8.5430x10 ⁷		1000
Watt hours	860.01	0.86001	3.6000x10 ¹⁰	3600	3.4130	2655.3	367.09	3.5529x10 ³	1.3410x10 ⁻³	8.5430x10 ¹	0.001	

Power	watts	kW	ft lb/sec	erg/sec	Btu/min	g cm/sec	kg cal/min	HP	lumens	joules/sec	Btu/hr
Watts		0.001	0.73756	1×10^7	0.056884	1.0197×10^4	0.01433	1.341×10^{-3}	668	1	3.41304
Kilowatts	1000		737.56	1×10^{10}	56.884	1.0197×10^7	14.3334	1.3410	6.68×10^5	1000	3413.04
Foot pounds per second	1.35582	1.3558×10^{-3}		1.3558×10^7	0.077124	1.3826×10^4	0.019433	1.8182×10^{-3}	906.28	1.3558	4.6274
Ergs per second	1×10^{-7}	1×10^{-10}	7.3756×10^{-8}		5.688×10^{-9}	1.0197×10^{-3}	1.4333×10^{-9}	1.3410×10^{-10}	6.6845×10^{-5}	1×10^{-7}	3.4130×10^{-7}
Btu ^a per minute	17.580	0.017580	12.9600	1.7580×10^8		1.7926×10^5	0.2520	0.023575	11751	17.580	60
Gram centimeters per second	9.8067×10^{-5}	9.8067×10^{-8}	7.2330×10^{-5}	980.665	5.5783×10^{-6}		1.4056×10^{-6}	1.3151×10^{-7}	0.065552	9.8067×10^{-5}	3.3470×10^{-4}
Kilogram calories per minute	69.767	0.069767	51.457	6.9770×10^8	3.9685	7.1146×10^5		0.093557	46636	69.769	238.11
Horsepower (U. S.)	745.7	0.7457	550	7.457×10^9	42.4176	7.6042×10^6	10.688		498129	745.7	2545.1
Lumens	1.496×10^{-3}	1.496×10^{-6}	1.0034×10^{-3}	1.496×10^4	8.5096×10^{-5}	15.254	2.1437×10^{-5}	2.0061×10^{-6}		1.496×10^{-3}	5.1069×10^{-3}
Joules per second	1	0.001	0.73756	1×10^7	0.056884	1.0197×10^4	0.01433	1.341×10^{-3}	668		3.41304
Btu ^a per hour	0.29299	2.9299×10^{-4}	0.21610	2.9299×10^6	0.01667	2.9878×10^3	4.1997×10^{-3}	3.9291×10^{-4}	195.80	0.29299	

^a British Thermal Units (Mean)

CONVERSION FACTORS FOR VARIOUS SUBSTANCES^a

Type Of Substance	Conversion Factors
Fuel	
Oil	1 bbl = 159 liters (42 gal)
Natural gas	1 therm = 100,000 Btu (approx.25000 kcal)
Gaseous Pollutants	
O ₃	1 ppm, volume = 1960µg/m ³
NO ₂	1 ppm, volume = 1880µg/m ³
SO ₂	1 ppm, volume = 2610µg/m ³
H ₂ S	1 ppm, volume = 1390 µg/m ³
CO	1 ppm, volume = 1.14 mg/m ³
HC (as methane)	1 ppm, volume = 0.654 mg/m ³
Agricultural products	
Corn	1 bu = 25.4 kg = 56 lb
Milo	1 bu = 25.4 kg = 56 lb
Oats	1 bu = 14.5 kg = 32 lb
Barley	1 bu = 21.8 kg = 48 lb
Wheat	1 bu = 27.2 kg = 60 lb
Cotton	1 bale = 226 kg = 500 lb
Mineral products	
Brick	1 brick = 2.95 kg = 6.5 lb
Cement	1 bbl = 170 kg = 375 lb
Cement	1 yd ³ = 1130 kg = 2500 lb
Concrete	1 yd ³ = 1820 kg = 4000 lb
Mobile sources, fuel efficiency	
Motor vehicles	1.0 mi/gal = 0.426 km/liter
Waterborne vessels	1.0 gal/naut mi = 2.05 liters/km
Miscellaneous liquids	
Beer	1 bbl = 31.5 gal
Paint	1 gal = 4.5 to 6.82 kg = 10 to 15 lb
Varnish	1 gal = 3.18 kg = 7 lb
Whiskey	1 bbl = 190 liters = 50.2 gal
Water	1 gal = 3.81 kg = 8.3 lb

^a Many of the conversion factors in this table represent average values and approximations and some of the values vary with temperature and pressure. These conversion factors should, however, be sufficiently accurate for general field use.