move large particles (the staining portion of atmospheric dust).

Dust Holding Capacity - Measurement of the total amount of dust a filter is able to hold during a dust-loading test.

Electrostatic Attraction - Small particles attracted to fibers, and after being contacted, retained there by a weak electrostatic force.

Electrostatic Filter - A filter that uses electrostatically enhanced fibers to attract and retain particles.

Energy - Energy has units of force multiplied by distance. It is commonly referred to as "work". If you weigh 200 pounds and climb straight up a ten foot ladder, you do 200*10 foot-pounds of work. In metric units, the common units are called "joules". One joule equals one Newton-meter. In metric units, if you weigh 850 Newtons and climb straight up a 3 meter ladder, you do 2550 N-m of work. Energy divided by time is called "power".

Fahrenheit - A temperature scale. Pure water freezes at 32°F and boils at 212°F (at one atmosphere of pressure). To convert °F to °C, subtract 32 and divide by 1.8. Fahrenheit and Rankine have the same scale, but are offset by 459.67 relative to one another. ie: 0°R equals –459.67°F and 0°F = 459.67°R.

Fan Laws - Equations used to calculate fan flow, pressure, and power at different fan speeds, different air temperatures, and different air pressures.

Filter Bypass - Airflow around a filter or through an unintended path.

Filter Face Velocity - Air stream velocity just prior to entering the filter.

Filter Performance - A description of a filter's collection efficiency, pressure drop, and dust-holding capacity over time.

High Efficiency Filter - Primarily used to collect particles <1 micrometer.

Gas - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures.

Gas-Phase Filter - Composed of sorbent medium, e.g., natural zeolite, alumina-activated carbon, specialty carbons, synthetic zeolite, polymers.

Impaction - Particle colliding with a fiber due to particle inertia.

Large Particle - Particles greater than 1 micrometer in diameter.

Life-Cycle Cost - Sum of all filter costs from initial investment to disposal and replacement, including energy and maintenance costs.

Low Efficiency Filter - Primarily used to collect particles >1 micrometer.

Mass Transfer Zone - Adsorbent bed depth required to reduce the chemical vapor challenge to the breakthrough concentration.

Mechanical Filter Collection Mechanism - Governs particulate air filter performance.

Packing Density - Ratio of fiber volume to total filter volume.

Particulate Filter - Collects particles only—mechanically or electrostatically.

HVAC Component	Estimated use of fan power as a percentage of total available (approx.)
Supply grille or register	3%
Return grilles or registers	13-20%%
Dampers	6%
Flexible duct	3%
Solid wall duct	6%
Elbows or turns	13-20%
Cooling or heating coil	8-12%
Heat exchanger	10% to 16% (clean filters)
Single stage filters (MERV 13)	10% to 16% (clean filters)
Second stage filters (MERV 14)	16% to 33% (clean filters)
Actual values will vary based upon design velocity, component selection and the intricacy of the entire system. Values are shown for example purposes.	

Energy Calculation

To calculate the energy cost to move air through any component in your system, the following equation applies:

1. Volumetric Flow Rate "Q", stated in ft^3/min (cubic feet per minute).
2. Total Pressure in inches of water (resistance due to friction of ducts, coils, filters, etc.), and ΔP of the component under consideration.
3. Density factor of the gas being collected "df" (dimensionless).
4. Efficiency of the fan, "η" (dimensionless).

These are combined into the air power equation:

Power (horsepower) = (Q) (TP) (df) (η) (6356).

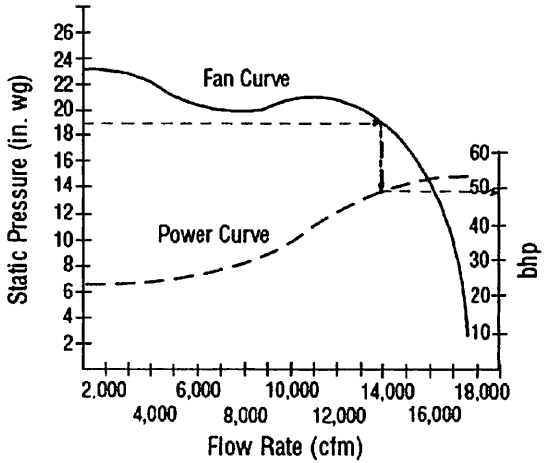
Small reductions in the numerator can have a significant cost impact.

Following the rule of thumb of changing the filter when it doubles its initial pressure drop can also provide significant energy savings. As a filter loads with dirt, its resistance to airflow increases, forcing the fan to work harder to deliver the air for heating and cooling requirements. This change in filter resistance can affect the balance of the system, increasing energy costs.

Fan performance is typically defined by a plot of static pressure and power required over a range of fan-generated airflow. Understanding this relationship is essential to initial design and proper selection of components, and replacement components such as air filters. Fan efficiency is the ratio of the power imparted to the airstream to the power delivered by the motor. The power of the airflow is the product of the pressure and the flow, corrected for units consistency. The equation for total efficiency is:

$$\text{Total Efficiency} = \frac{\text{Total Pressure x Airflow}}{\text{bhp x 6.362}}$$

Where:
Total Pressure is in inches of water
Airflow is in cubic feet per minute (cfm)
bhp is brake horsepower



An important aspect of a fan performance curve is the best efficiency point (BEP), where a fan operates most cost effectively in terms of both energy efficiency and maintenance considerations. Operating a fan near its BEP improves its performance and reduces wear, allowing longer intervals between repairs. Moving a fan's operating point away from its BEP increases bearing loads and noise.

On the above fan curve, the optimum operating range is within the intersecting points where the straight dotted line intersects the fan curve. Variance in either direction can translate into higher energy costs. This graph is fan specific and the curve and intersections will vary from fan to fan. Consult your fan manufacturer for model specific fan curves.

Each fan manufacturer can provide a fan curve that allows a technician to adjust fan operating parameters to provide maximum air at a minimal energy investment. In most modern systems, fan adjustment is handled automatically by a variable frequency drive (VFD). The VFD can reduce the motor speed when full flow is not required, thereby reducing the power and the electrical energy used. The intent of a VFD is to match system airflow to actual heating and cooling demands. Most HVAC systems are designed to keep the building cool on the hottest days and warm on the coldest days. Therefore, the HVAC system needs to work at full capacity only on the 10, or so, hottest days and the 10, or so, coldest days of the year. On the other 345 days, the HVAC system can operate at a reduced capacity. A variable air volume system with variable speed drives adjusts the motor speed enabling closer matching of motor output to load with resultant energy savings.

VFDs decrease energy losses by lowering overall system flow.

By slowing the fan and lessening the amount of unnecessary energy imparted to the airstream, VFDs offer substantial savings with respect to the cost-per-unit volume of air moved. When fan speed decreases, the curves for fan performance and brake horsepower move toward the origin. Fan efficiency increases, providing an essential cost advantage during periods of low system demand. Keeping fan efficiency as high as possible across variations in the system's flow requirements reduces fan operating costs. VFDs eliminate the reliance on mechanical

Bioaerosols - A suspension of particles of biological origin.

Breakthrough Concentration - Saturation point of downstream contaminant buildup, which prevents the collection ability of a sorbent to protect against gases and vapors.

Breakthrough Time - Elapsed time between the initial contact of the toxic agent at a reported challenge concentration on the upstream surface of the sorbent bed and the breakthrough concentration on the downstream side.

CBR Agent - Airborne chemical, biological, or radiological contaminant.

Celsius (Centigrade) - A temperature scale. Pure water freezes at 0° C and boils at 100° C (at one atmosphere of pressure). To convert °C to °F, multiply by 1.8 and add 32. Celsius and Kelvin have the same scale, but are offset from one another by 273.15. i.e.: 0° K equals -273.15° C and 273.15° K equals 0° C.

cfm - Cubic feet per minute. This is a general measure of volumetric ~ ow rate. Fans are normally rated in terms of CFM. In order for fan ratings to have meaning, they must be tested under identical, rigidly controlled conditions.

Challenge Concentration - Airborne concentration of the hazardous agent entering the sorbent.

Channelling - Air passing through portions of the sorbent bed that offer low airflow resistance due to non-uniform packing, irregular particle sizes, etc.

Chemisorption - Sorbent capture mechanism dependent on chemically active medium (involves electron transfer).

Collection Efficiency - Fraction of entering particles that are retained by the filter (based on particle count or mass).

Composite Efficiency Value - Descriptive rating value for a clean filter to incrementally load different particle sizes.

Convection - Heat transfer from a solid into a liquid or gas. The energy transferred through the heat sink leaves via convection to air or water. Convection increases with increasing temperature differential, increasing surface area, and increasing convection coefficient.

Convection Coefficient - A measure of how efficiently a fluid (liquid or gas) transfers heat to or from a solid. This value depends on many factors including fluid density, fluid speed, fluid viscosity, solid geometry, and a few others not mentioned here.

Decibels - A logarithmic scale used in measuring sound.

Differential Temperature - The difference between two temperatures. Convection between a solid and liquid depends on temperature differential. To convert a differential temperature in °C to °F, multiply by 1.8. To convert a differential temperature in °F to °C, divide by 1.8. Do not add or subtract 32 when converting differentials. You need only add or subtract 32 when converting absolute temperatures.

Diffusion - Particle colliding with a fiber due to random (Brownian) motion.

Dust Spot Efficiency - Measurement of a filter's ability to re-

MISCELLANEOUS

3 inches =	1 palm
4 inches =	1 hand
6 inches =	1 span
18 inches =	1 cubit
21.8 inches =	1 Bible cubit
2 1/2 feet =	1 military pace

MEASURE OF VOLUME

1 cubic centimeter =	0.061 cu. inch
1 cubic Inch =	16.39 cubic cent.
1 cubic decimeter =	0.0353 cubic foot
1 cubic foot =	28.317 cubic dec.
1 cubic meter =	1.308 cubic yards
1 cubic yard =	0.7646 cubic meter
1 stere =	0.2759 cord
1 cord =	3.624 steres
1 liter =	0.908 qt. dry / 1.0567 qt. liq.
1 quart dry =	1.101 liters
1 quart liquid =	0.9463 liter
1 dekaliter =	2.6417 gals - 1.135 pecks
1 gallon =	0.3785 dekaliter
1 peck =	0.881 dekaliter
1 hektoliter =	2.8375 bushels
1 bushel =	0.3524 hektoliter

Industry Terms

µm - Micrometer or micron, one-millionth of a meter

Absolute Zero - Absolute zero is the temperature at which molecular activity ceases. Absolute zero equals 0 Kelvin, -273.15°C, and –459.67°F. All material properties change according to temperature.

ACFM - Actual Cubic Feet per Minute. This is a measure of airflow referenced to the current density of the gas. The mass flow rate of the air equals the ACFM multiplied by the air density.

Aerosols - Solid and liquid airborne particles, typically ranging in size from 0.001 to 100 µm.

Ambient - In our discussion, refers to room conditions, particularly room temperature.

Amperes - Units for measuring the amount of electrical current. Electrical current is analogous to a rate of flow such as gallons per minute (liquid flow) or cubic feet per minute (airflow).

Arrestance - Ability of a filter to capture a mass fraction of coarse test dust.

Axial Fan - A fan that propels air in a direction parallel to its axis of rotation. Virtually all fans used in computers today are of this type. The alternative is a centrifugal (or radial) fan.

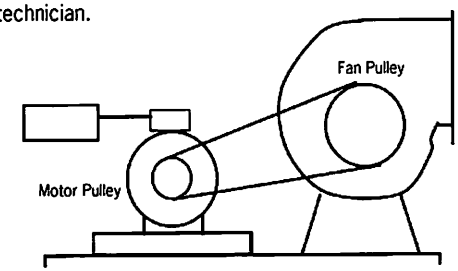
components, providing an attractive operational advantage, especially in "dirty" airstreams. A system with a VFD will adjust to the filter's resistance to airflow even as the filter loads with contaminants.

For initial design purposes a design engineer should calculate:

- Initial resistance at airflow plus 0.20" for prefilters
- Initial resistance at airflow plus 0.30" w.g. for final filters

...as part of the overall system average resistance to airflow.

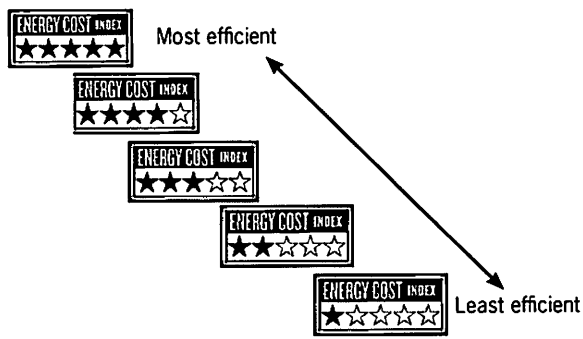
If a building uses a constant-volume air handling system with no variable speed drives, the system runs at full speed all the time. If optimal energy savings are to be obtained by using air filters with a lower system resistance, then some mechanical modifications may have to be made. Usually this involves a simple pulley change. We recommend that these changes be made by a qualified technician.



On older belt-driven systems a motor pulley must be changed or chived to ensure that the fan is operating within the parameters of the fan's curve. Changing system components on this type of system without taking this step could actually cause the system to use more energy.

Energy Cost Index (ECI)

Another item that should be considered when selecting a filter is whether that filter will provide the efficiency as published throughout the life of the filter. Some filters use an electret charge to enhance efficiency, but the charge dissipates over time, and the filter's efficiency drops. The Energy Cost Index (ECI) looks at a filter's energy use over its expected life and includes a factor that penalizes the filter rating, if it drops in efficiency. The Energy Cost Index (ECI) is an easy way to compare the energy efficiency of one manufacturer's filter against another and then choose the one that will work best for you. Based on a five-star scale, the ECI is an indicator of what the filter will cost over its lifetime. The best rating—five stars—indicates that the filter is one of the most energy-efficient, longest-lasting filters available.



Handy Industry Conversions

ATMOSPHERES — atm (Standard at sea-level pressure)

x 101.325 =	Kilopascals (kPa) absolute
x 14.696 =	Pounds-force per square inch absolute (psia)
x 76.00 =	Centimeters of mercury (cm Hg) at 0°C
x29.92 =	Inches of mercury (inHg) at 0°C
x 33.96 =	Feet of water (ft H_2O) at 68°F
x 1.01325 =	Bars (bar) absolute
x 1.0332 =	Kilograms-force per square centimeter (kg/cm²) absolute
x 1.0581 =	Tons-force per square foot (tonf/ft²) absolute
x760 =	Torr (torr) (= mm Hg at 0°C)

BARRELS, LIQUID, U.S. — bbl

x 0.11924 =	Cubic meters (m³)
x 31.5 =	U.S. gallons (U.S. gal) liquid

BARRELS, PETROLEUM — bbl

x 0.15899 =	Cubic meters (m³)
x 42 =	U.S. gallons (U.S. gal) oil

BARS — bar x 100

x 14.504 =	Kilopascals (kPa)
x 33.52 =	Pounds-force per square inch (psi) = Feet of water (ft H_2O) at 68°F
x 29.53 =	Inches of mercury (in. Hg) at 0°C
x 1.0197 =	Kilograms-force per square centimeter (kg/cm²)
x 0.98692 =	Atmospheres (atm) sea-level standard
x 1.0443 =	Tons-force per square foot (tonf/ft²)
x 750.06 =	Torr (torr) (= mm Hg at 0°C)

BRITISH THERMAL UNITS — Btu

x 1055 =	Joules (J)
x 778 =	Footpounds-force (ft • lbf)
x 0.252 =	Kilocalories (kcal)
x 107.6 =	Kilogram-force-meters (kgf • m)
x 2.93 x 10^{-4} =	Kilowatt-hours (kW • h)
x 3.93 x 10^{-4} =	Horsepower-hours (hp • h)

BRITISH THERMAL UNITS PER MINUTE — Btu/mln

x 17.58 =	Watts (W)
x 12.97 =	Foot-pounds-force per second (ft • lbf/s)
x 0.02358 =	Horsepower (hp)

CENTARES

x 1 =	Square meters (m)

CENTIMETERS — cm

x 0.3937 =	Inches (in)

TROY WEIGHT

24 grains =	1 pwt.
20 pwt =	1 ounce
12 ounces =	1 pound

CLOTH MEASURE

2 1/8 inches =	1 nail
4 nails =	1 quarter
4 quarters =	1 yard

CUBIC MEASURE

1,728 cubic inches =	1 cubic foot
27 cubic feet =	1 cubic yard
128 cubic feet =	1 cord (wood)
40 cubic feet =	1 ton (shipping)
2,150.42 cubic inches =	1 standard bushel
231 cubic inches =	1 U.S. standard gal.
1 cubic foot =	about 4/5 of a bushel

DRY MEASURE

2 pints =	1 quart
8 quarts =	1 peck
4 pecks =	1 bushel
36 bushels =	1 chaldron

MARINERS' MEASURE

6 feet =	1 fathom
120 fathoms =	1 cable length
7 1/2 cable lengths =	1 mile
5,280 feet =	1 statute mile
6,080.2 feet =	1 nautical mile

SURVEYORS' MEASURE

7.92 inches =	1 link
25 links =	1 rod
4 rods =	1 chain
10 sq. chains or 160 sq. rod =	1 acre
640 acres =	1 sq. mile
36 sq. miles (6 miles sq) =	1 township

TIME MEASURE

60 seconds =	1 minute
60 minutes =	1 hour
24 hours =	1 day
7 days =	1 week
28, 29, 30 or 31 days =	1 calendar month
30 days =	1 month in compound interest
365 days =	1 year
366 days =	1 leap year

1 In. water (H_2O)

= 0.0361 lb. per sq. in. = 5.196 lb. per sq. ft.
= 0.0735 in. mercury = 1.876 mm. mercury
= 0.002456 atmospheres = 0.5774 oz. per sq. in.
= 25.4 mm. of water = 0.08333 ft. of water

1 In. mercury

= 0.491 lb. per sq. in. = 70.70 lb. per sq. ft.
= 25.4 mm. mercury = 7.86 oz. per sq. in.
= 0.03342 atmospheres = 345.6 mm. water
= 13.61 in. water = 1.134 ft. water

1 mm. mercury

= 0.01934 lb. per sq. in. = 2.789 lb. per sq. ft.
= 0.3094 oz. per sq. in. = 0.001316 atmospheres
= 0.5357 in. water = 0.04464 ft. water
= 13.61 mm water = 0.03937 in. mercury

1 lb. per sq. in.

= 144 lb. per sq. ft. = 16 oz. per sq. in.
= 51.71 mm. mercury = 2.036 in. mercury
= 0.06804 atmospheres = 703.7 mm. water
= 27.70 in. water = 2.309 ft. water
= 0.06895 megabars (or megadynes) per sq. cm.
= 0.0703 kg. per sq. cm.

1 oz. per sq. in.

= 0.0625 lb. per sq. in. = 9.00 lb. per sq. ft.
= 1.733 in. water = 0.1441 ft. water
= 0.1272 in. mercury = 3.23 mm. mercury
= 0.00425 atmospheres = 44.02 mm. water

Additional Tidbits

1 in. of water resistance lowers wt. per cu. ft. of air by 1/4 of 1%.

1 in. of mercury represents 900 ft. difference in elevation at sea level to 4,000 ft.

1 in. of mercury represents 1,000 ft. difference in elevation at 4,000 to 6,000 ft. elevation.

1 in. of water represents 66 ft. difference in elevation at sea level to 4,000 ft.

1 in. of water represents 74 ft. difference in elevation at 4,000 to 6,000 ft. elevation.

1,000 ft. difference in elevation at sea level represents 1.11 in. of mercury.

1,000 ft. difference in elevation at 4,000 ft. represents 1 in. of mercury.

1,000 ft. difference in elevation at sea level represents 15.2 in. water.

1,000 ft. difference in elevation at 4,000 ft. represents 13.6 in. water.

1 gm. per sq. cm. = 0.394 in. water = 0.02896 in. mercury

CENTIMETERS OF MERCURY — cm Hg at 0°C

x 1.3332 = Kilopascals (kPa)
x 0.013332 = Bars (bar)
x 0.4468 = Feet of water (ft H_2O) at 68°F
x 5.362 = Inches of water (inH_2O) at 68°F
x 0.013595 = Kilograms-force per square centimeter (kg/cm^2)
x 27.85 = Pounds-force per square foot (lb f/ft^2)
x 0.19337 = Pounds-force per square inch (psi)
x 0.013158 = Atmospheres (atm) standard
x 10 = Torr (torr) (= mm Hg at 0°C)

CENTIMETERS PER SECOND — cm/s

x 1.9685 = Feet per minute (ft/min)
x 0.03281 = Feet per second (ft/s)
x 0.03600 = Kilometers per hour (km/h)
x 0.6000 = Meters per minute (m/min)
x 0.02237 = Miles per hour (mph)

CUBIC CENTIMETERS — cm^3

x 3.5315×10^{-5} = Cubic feet (ft^3)
x 6.1024×10^{-2} = Cubic inches (in^3)
x 1.308×10^{-6} = Cubic yards (yd^3)
x 2.642×10^{-4} = U.S. gallons (U.S. gal)
x 2.200×10^{-4} = Imperial gallons (imp gal)
x 1000×10^{-3} = Liters (l)

CUBIC FEET — ft^3

x 0.02832 = Cubic meters (m^3)
x 2.832×10^4 = Cubic centimeters (cm^3)
x 1728 = Cubic inches (in^3)
X 0.03704 = Cubic yards (yd^3)
x 7.481 = U.S. gallons (U.S. gal)
x 6.229 = Imperial gallons (imp gal)
x 28.32 = Liters (l)

CUBIC FEET PER MINUTE — cfm

x 472.0 = Cubic centimeters per second (cm^3/s)
x 1.699 = Cubic meters per hour (m^3/h)
x 0.4720 = Liters per second (l/s)
x 0.1247 = U.S. gallons per second (U.S. gps)
x 62.30 = Pounds of water per minute (lb H_2O/min) at 68°F

CUBIC FEET PER SECOND — cfs

x 0.02832 = Cubic meters per second (m^3)
x 1.699 = Cubic meters per minute (m^3/min)
x 448.8 = U.S. gallons per minute (U.S. gpm)
x 0.6463 = Million U.S. gallons per day (U.S. gpd)

CUBIC INCHES — in^3

x 1.6387×10^{-5} =	Cubic meters (m^3)
x 16.387 =	Cubic centimeters (cm^3)
x 0.016387 =	Liters (l)
x 5.787×10^{-4} =	Cubic feet (ft^3)
x 2.143×10^{-5} =	Cubic yards (yd^3)
x 4.329×10^{-3} =	U.S. gallons (U.S. gal)
x 3.605×10^{-3} =	Imperial gallons (imp gal)

CUBIC METERS — m^3

x 1000 =	Liters (l)
x 35.315 =	Cubic feet (ft^3)
x 61.024×10^3 =	Cubic inches (in^3)
x 1.3080 =	Cubic yards (yd^3)
x 264.2 =	U.S. gallons (U.S. gal)
x 220.0 =	Imperial gallons (imp gal)

CUBIC METERS PER HOUR — m^3/h

x 0.2778 =	Liters per second (l/s)
x 2.778×10^{-4} =	Cubic meters per second (m^3s)
x 4.403 =	U.S. gallons per minute (U.S. gpm)

CUBIC METERS PER SECOND — m^3/s

x 3600 =	Cubic meters per hour (m^3/h)
x 15.85×10^{-3} =	U.S. gallons per minute (U.S. gpm)

CUBIC YARDS — yd^3

x 0.7646 =	Cubic meters (m^3)
x 764.6 =	Liters (l)
x 7.646×10^5 =	Cubic centimeters (cm^3)
x 27 =	Cubic feet (ft3)
x 46,656 =	Cubic inches (in^3)
x 201.97 =	U.S. gallons (U.S. gal)
x 168.17 =	Imperial gallons (imp gal)

DEGREES ANGULAR — (°)

x 0.017453 =	Radians (rad)
x 60 =	Minutes (')
x 3600 =	Seconds
x 1.111 =	Grade (gon)

DEGREES PER SECOND, ANGULAR — (°/s)

x 0.017453 =	Radians per second (rad/s)
x 0.16667 =	Revolutions per minute (rpm)
x 2.7778×10^{-3} =	Revolutions per second (rps)

DRAMS — (dr)

x 1.7718 =	Grams (g)
x 27.344 =	Grains (gr)
x 0.0625 =	Ounces (oz)

Heat & Energy Units

1 hp-hr.	0.7457 kilowatt hour (kw-hr)
	1,980,000 foot pounds (ft-lb)
	2,545 British thermal units (Btu)
	273,745 kg-m
	0.1849 pounds of carbon oxidized with perfect efficiency
	2.622 pounds of water evaporated at 212° F
	16.96 pounds of water raised from 62° to 212° F
1 pound of carbon oxidized with perfect efficiency	14,520 British thermal units (Btu)
	1.1085 pounds anthracite oxidized (varies)
	2.315 pounds of dry wood oxidized (varies)
	26.4 cubic feet manufactured gas (varies)
	12.9 cubic feet natural gas
	14.255 kilowatt hour, 5.709 horsepower hour, 11,300,000 foot pounds
	14.97 pounds of water raised from 62° to 212° F
1 pound of water evaporated from and at 212° F	0.2844 kilowatt hour
	0.3814 horsepower hour
	970.2 British thermal units (Btu)
	104,400 kg-m
	1,023,500 Joules
	756,500 foot pounds
	0.0668 pounds of carbon oxidized with perfect efficiency

1 kg.-cal. =	3.9685 Btu
1 Btu =	0.2520 kg.-cal.
1 kg.-cal. per kilogram =	1.8000 Btu per lb.
1 Btu per pound =	0.5555 kg.-cal. per kg.
1 kg.-cal. per liter =	112.37 Btu per cu. ft.
1 Btu per cu. ft. =	0.0089 kg.-cal. per lb.
1 kg.cal. per cu. m. =	0.1124 Btu per cu. ft.
1 Btu per cu. ft. =	8.8987 kg.-cal. per cu. m.

Pressure equivalents

1 Atmosphere

= 14.696 lb. per sq.in. =	2116.3 lb. per sq.ft.
= 33.96 ft. of water =	407.52 in. water
= 29.92 in. of mercury =	760 mm. mercury
= 234.54 oz. per sq. in. =	10,340 mm. water

Avoirdupois weight

1 dram =	27.3437 grains
1 ounce =	16 drams
1 pound =	16 ounces
1 quarter =	25 pounds
1 hundredweight =	4 quarters
1 short ton =	2,000 pounds
1 long ton =	2,240 pounds
1 pound =	7,000 grains

Heat and energy units

1 ton (ref rig.) =	200 Btu/ min.

Apothecaries' weight

1 scruple =	20 grains
1 ounce =	8 drams
1 dram =	3 scruples
Grain =	0.0648 g
Oz. =	28.3495 g
Lb . =	0.4536 kg
1 pound =	12 ounces
Ton (sht.) =	907.1848 kg.
Ton (sht.) =	0.9072 ton (met.)
Ton (lg.) =	1.0160 ton (met.)

Pressure

1 kg. per sq. cm. =	14.223 lb. per sq. in.
1 lb. per sq. in. =	0.0703 kg. per sq. cm.
1 kg. per sq. m. =	2048 lb. per sq. ft.
1 lb. per sq. ft. =	4.8824 kg. per sq. m.
1 kg. per sq. cm. =	0.9678 normal atmosphere

Heat & Energy Units

1 kw-hr.	1,000 watts per hour (w/hr)
	1.3410 horsepower per hour (hp-hr)
	2,655,217 foot/pounds (ft-lb)
	3,600,000 Joules
	3,413 British thermal units (Btu)
	860 kg-cal
	367,098 kg-m
	0.235 pounds of carbon oxidized with perfect efficiency
	3,518 pounds of water evaporated from and at 212° F
	22.76 pounds of water raised from 62° to 212° F

FATHOMS

x 1.8288 =	Meters (m)
x 6 =	Feet (ft)

FEET — ft

x 0.3048 =	Meters (m)
x 30.480 =	Centimeters (cm)
x 12 =	Inches (in)
x 0.333 =	Yards (yd)

FEET OF WATER — ft H^2O at 68°F

x 2.984 =	Kilopascals (kPa)
x 0.02984 =	Bars (bar)
x 0.8811 =	Inches of mercury (in. Hg) at 0°C
x 0.03042 =	Kilograms-force per square centimeter (kg/cm^2)
x 62.32 =	Pounds-force per square foot (lbf/ft^2)
x 0.4328 =	Pounds-force per square inch (psi)
x 0.02945 =	Standard atmospheres

FEET PER MINUTE

x 0.5080 =	Centimeters per second (cm/s)
x 0.01829 =	Kilometers per hour (km/h)
x 0.0051 =	Meters per second (mps)
x 0.3048 =	Meters per minute (m/min)
x 0.016667 =	Feet per second (ft/s)
x 0.01136 =	Miles per hour (mph)

FEET PER SECOND PER SECOND — ft/s^2

x 0.3048 =	Meters per second per second (m/s^2)
x 30.48 =	Centimeters per second per second (cm/s^2)

FOOT-POUNDS-FORCE — ft • lbf

x 1.356 =	Joules (J)
x 1.285×10^{-3} =	British thermal units (Btu)
x 3.239×10^{-4} =	Kilocalories (kcal)
x 0.13825 =	Kilogram-force-meters (kgf • m)
x 5.050×10^{-7} =	Horsepower-hours (hp • h)
x 3.766×10^{-7} =	Kilowatt-hours (kW • h)

GALLONS U.S — U.S. gal

x 3785.4 =	Cubic centimeters (cm^3)
x 3.7854 =	Liters (l)
x 3.7854 x 10-3 =	Cubic meters (m^3)
x 231 =	Cubic inches (in^3)
x 0.13366 =	Cubic feet (ft^3)
x 4.951 x 10-3 =	Cubic yards (yd^3)
x 8 =	Pints (pt) liquid
x 4 =	Quarts (qt) liquid

GALLONS U.S — U.S. gal (continued)

x 0.8327 =	Imperial gallons (Imp gal)
x 8.328 =	Pounds of water at 60°F in air
x 8.337 =	Pounds of water at 60°F in vacuum

GALLONS, IMPERIAL — Imp gal

x 4546 =	Cubic centimeters (cm^3)
x 4.546 =	Liters (l)
x 4.546 x 10^{-3} =	Cubic meters (m^3)
x 0.16054 =	Cubic feet (ft^3)
x 5.946 x 10^{-3} =	Cubic yards (yd^3)
x 1.20094 =	U.S. gallons (U.S. gal)
x 10.000 =	Pounds of water at 62°F in air

GALLONS, PER MINUTE, U.S. — U.S. gpm

x 0.22715 =	Cubic meters per hour (m^3h)
x 0.06309 =	Liters per second (l/s)
x 8.021 =	Cubic feet per hour (cfh)
x 2.228 x 10^{-3} =	Cubic feet per second (cfs)

GRAINS — gr av. or troy

x 0.0648 =	Grams (g)

GRAINS PER CUBIC FOOT

x 2288.1 =	milligrams per cubic meter (mg/m^3)

GRAINS PER U.S. GALLON — gr/U.S. gal at 60°F

x 17.12 =	Grams per cubic meter (g/m^3)
x 17.15 =	Parts per million by weight in water
x 142.9 =	Pounds per million gallons

GRAINS PER IMPERIAL GALLON — gr/Imp gal at 62°F

x 14.25 =	Grams per cubic meter (g/m^3)
x 14.29 =	Parts per million by weight in water

GRAMS — g

x 15.432 =	Grains (gr)
x 0.035274 =	Ounces (oz) av
x 0.032151 =	Ounces (oz) troy
x 2.2046 x 10^{-3} =	Pounds (lb)

GRAMS-FORCE — gf

x 9.807 x 10^{-3} =	Newtons (N)

GRAMS—FORCE PER CENTIMETER — gf/cm

x 98.07 =	Newtons per meter (N/m)
x 5.600 x 10^{-3} =	Pounds-force per inch (lbf/in)

GRAMS PER CUBIC CENTIMETER — g/cm^3

x 62.43 =	Pounds per cubic foot (lb/ft^3)
x 0.03613 =	Pounds per cubic inch (lb/in^3)

TEMPERATURES (Fahrenheit)

Milk Freezes 30° above Zero
Water Freezes 32° above Zero
Olive Oil Freezes 36° above Zero
Wines Freeze 20° above Zero
Vinegar Freezes 28° above Zero
Alcohol Boils at 173° above Zero
Water Boils at 212° above Zero
Eggs Hatch 104° above Zero
Petrol Boils at 360° above Zero
Blood Heat 98.4° above Zero

Linear measure

1 foot =	12 inches
1 yard =	3 feet
1 rod =	5 1/2 yards
1 furlong =	40 rods
1 stat mile =	8 furlongs
1 stat mile =	5,280 feet
1 naut mile =	6,080 feet
1 league =	3 miles

Circular measure

1 minute =	60 seconds
1 degree =	60 minutes
1 circle =	4 quadrants = 2 π radians or 360 degrees
1 radian =	57.296 degrees
1 quadrant =	90°

Square measure

144 sq. in. =	1 sq. ft.
9 sq. ft. =	1 sq. yd.
30 1/4 sq. yd. =	1 sq. rod
160 sq. rods =	1 acre
43,560 sq. ft. =	1 acre
640 acres =	1 sq. mile

Liquid measure

1 pint =	4 gills
1 quart =	2 pints
1 gallon =	4 quarts
1 barrel =	31 1/2 gallons
1 hogshead =	2 barrels
1 Imp. gal. =	1.2 gal. (U.S.)

Volume

1 cu. foot =	7.48 gallons
1 gallon =	231 cu. inches
1 gal./hr. =	2.135 oz./ min.

TONS-MASS — tonm long

x 1016 =	Kilograms (kg)
x 2240 =	Pounds (lb) av
x 1.1200 =	Tons (ton) short

TONNES — t metric ton, miller

x 1000 =	Kilograms (kg)
x 2204.6 =	Pounds (lb)

TONNES-FORCE — tf metric ton-force

x 980.7 =	Newtons (N)

TONS — ton short

x 907.2 =	Kilograms (kg)
x 0.9072 =	Tonnes (t)
x 2000 =	Pounds (lb) av
x 32000 =	Ounces (oz) av
x 2430.6 =	Pounds (lb) troy
x 0.8929 =	Tons (ton) long

TONS OF WATER PER 24 HOURS AT 60°F

x 0.03789 =	Cubic meters per hour (m^3h)
x 83.33 =	Pounds of water per hour (lb/h H_2O) at 60°F
x 0.1668 =	U.S. gallons per minute (U.S. gpm)
x 1.338 =	Cubic feet per hour (cf/h)

WATTS — W

x 0.05690 =	British thermal units per minute (Btu/min)
x 44.25 =	Foot-pounds force (ft- lb/min)
x 0.7376 =	Foot-pounds-force per second (ft- lbf/s)
x1.341 x10^{-3} =	Horsepower (hp)
x 0.01433 =	Kilocalories per minute (kcal/min)

WATT-HOURS — W • h

x 3600 =	Joules (J)
x 3.413 =	British thermal units (Btu)
x 2655 =	Foot-pounds-force (ft • lbf)
x 1.341 x 10^{-3} =	Horsepower-hours (hp • h)
x 0.860 =	Kilocalories (kcal)
x 367.1 =	Kilograms-force-meters (kgf • m)

APPROXIMATE METRIC EQUIVALENTS

1 decimeter =	4 inches
1 liter =	1.06 quarts liquid, 0.9 qt. dry
1 meter =	1.1 yards
1 kilometer =	5/8 of a mile
1 hektolite =	2 5/8 bushels
1 hectare =	2 1/2 acres
1 kilogram =	2 1/5 pounds
1 metric ton =	2,204.6 pounds

GRAMS PER LITER — g/l

x 58.42 =	Grains per U.S. gallon (gr/U.S. gal)
x 8.345 =	Pounds per 1000 U.S. gallons
x 0.06243 =	Pounds per cubic foot (lb/ft^3)
x 1002 =	Parts per million by mass (weight) In water at 60°F

HECTARES — he

x 1.000 x 10^4 =	Square meters (m^2)
x 1.0764 x 10^6 =	Square feet (ft^2)

HORSEPOWER — hp

x 745.7 =	Watts (W)
x 0.7457 =	Kilowatts (kW)
x 33,000 =	Foot-pounds-force per minute (ft • lbf/min)
x 550 =	Foot-pounds-force per second (ft • lbf/s)
x 42.43 =	British thermal units per minute (Btu/min)
x 10.69 =	Kilocaiories per minute (kcal/min)
x 1.0139 =	Horsepower (metric)

HORSEPOWER — hp boiler

x 33,480 =	British thermal units per hour (Btu/h)
X 9.809 =	Kilowatts (kW)

HORSEPOWER-HOURS — hp • h

x 0.7457 =	Kilowatt-hours (kW • h)
x 1.976 x 10^6 =	Foot-pounds-force (ft • lbf)
x 2545 =	British thermal units (Btu)
x 641.5 =	Kilocalories (kcal)
x 2.732 x 10^6 =	Kilogram-force-meters (kgf • m)

INCHES — In

x 2.540 =	Centimeters (cm)

INCHES OF MERCURY — In Hg at 0°C

x 3.3864 =	Kilopascals (kPa)
x 0.03386 =	Bars (bar)
x 1.135 =	Feet of water (ftH_2O) at 68°F
x 13.62 =	Inches of water (In H_2O) at 68°F
x 0.03453 =	Kilograms-force per square centimeter (kg/cm^2)
x 70.73 =	Pounds-force per square foot (lbf/ft^2)
x 0.4912 =	Pounds-force per square inch (psi)
x 0.03342 =	Standard atmospheres

INCHES OF WATER — In H_2O at 68°F

x 0.2487 =	Kilopascals (kpa)
x 2.487 x 10^{-3} =	Bars (bar)
x 0.07342 =	Feet of water (ft H_2O) at 68°F
x2.535 x10^{-3} =	Inches of mercury (in Hg) at 0°C
x 0.5770 =	Ounces-force per square inch (ozf/in^2)

INCHES OF WATER — In H_2O at 68°F (Continued)

x 5.193 =	Pounds-force per square foot (lbf/ft^2)
x 0.03606 =	Pounds-force per square inch (psi)
x 2.454×10^{-3} =	Standard atmospheres

JOULES — J

x 0.9484×10^{3} =	British thermal units (Btu)
x 0.2390 =	Calories (cal) thermochemical
x 0.7376 =	Foot-pounds-force (ft • lbf)
x 2.778×10^{-4} =	Watt-hours (W • h)

KILOGRAMS — kg

x 2.2046 =	Pounds (lb)
x 1.102×10^{3} =	Tons (ton) short

KILOGRAMS-FORCE — kgf

x 9.807 =	Newtons (N)
x 2.205 =	Pounds-force (lbf)

KILOGRAMS-FORCE PER METER — kgf/m

x 9:807 =	Newtons per meter (N/m)
x 0.6721 =	Pounds-force per foot (lbf/ft)

KILOGRAMS-FORCE PER SQUARE CENTIMETER — kgf/cm^2

x 98.07 =	Kilopascals (kPa)
x 0.9807 =	Bars (bar)
x 32.87 =	Feet of water (ft H20) at 68°F
x 28.96 =	Inches of mercury (in Hg) at 0°C
x 2048 =	Pounds-force per square foot (lbf/ft^2)
x 14.223 =	Pounds-force per square inch (psi)
x 0.9678 =	Standard atmospheres

KILOGRAMS-FORCE PER SQUARE MILLIMETER — kgf/mm^2

x 9.807 =	Megapascals (MPa)
x 1.000×10^{6} =	Kilograms-force per square meter (kgf/m^2)

KILOMETERS PER HOUR — km/h

x 27.78 =	Centimeters per second (cm/s)
x 0.9113 =	Feet per second (ft/s)
x 54.68 =	Feet per minute (ft/min)
x 16.667 =	Meters per minute (m/min)
x 0.53996 =	International knots (kn)
x 0.6214 =	Miles per hour (mph)

KILOMETERS PER HOUR PER SECOND — $km \cdot h^{-1} \cdot s^{-1}$

x 0.2778 =	Meters per second per second (m/s^2)
x 27.78 =	Centimeters per second per second (cm/s^2)
x 0.9113 =	Feet per second per second (ft/s^2)

KILOMETERS PER SECOND — km/s

x 37.28 =	Miles per minute (mi/min)

POUNDS PER CUBIC INCH — lb/in^3

x 2.768×10^{4} =	Kilograms per cubic meter (kg/m^3)
x 27.68 =	Grams per cubic centimeter (g/cm^3)
x 1728 =	Pounds per cubic foot (lb/ft^3)

POUNDS-FORCE PER FOOT — lbf/ft

x 14.59 =	Newtons per meter (N/m)
x 1.488 =	Kilograms-force per meter (kgf/m)
x 14.88 =	Grams-force per centimeter (gf/cm)

POUNDS-FORCE PER SQUARE FOOT — lbf/ft2

x 47.88 =	Pascals (Pa)
x 0.01605 =	Feet of water (ft H_2O) at 66°F
x 4.882×10^{4} =	Kilograms-force per square centimeter (kgf/cm^2)
x 6.944×10^{4} =	Pounds-force per square Inch (psi)

POUNDS-FORCE PER SQUARE INCH — psi

x 6.895 =	Kilopascals (kPa)
x 0.06805 =	Standard atmospheres
x 2.311 =	Feet of water (ft H_2O) at 68°F
x 27.73 =	Inches of water (in H_2O) at 68°F
x 2.036 =	Inches of mercury (in Hg) at 0°C
x 0.07031 =	Kilograms-force per square centimeter (kgf/cm^2)

QUARTS — qt dry

x 1101 =	Cubic centimeters (cm^3)
x 67.20 =	Cubic inches (in^3)

QUARTS — qt liquid

x 946.4 =	Cubic centimeters (cm^3)
x 57.75 =	Cubic inches (in^3)

QUINTALS — obsolete metric mass term

x 100 =	Kilograms (kg)
x 220.46 =	Pounds (lb) U.S. av
x 101.28 =	Pounds (lb) Argentina
x 129.54 =	Pounds (lb) Brazil
x 101.41 =	Pounds (lb) Chile
x 101.47 =	Pounds (lb) Mexico
x 101.43 =	Pounds (lb) Peru

RADIANS — rad

x 57.30 =	Degrees (°) angular

RADIANS PER SECOND — rad/s

x 57.30 =	Degrees per second (°/s) angular

STOKES — St

x 10^{4} =	Square meters per second (m^2/s)
x 1.076×10^{4} =	Square feet per second (ft^2/s)

POISES — P

x 0.1000 =	Newton-seconds per square meter ($N \cdot s/m^2$)
x 100 =	Centipoises (cP)
x 2.0886×10^{-3} =	Pound-force-seconds per square foot ($lbf \cdot s/ft^2$)
x 0.06721 =	Pounds per foot second ($lb/ft \cdot s$)

POUNDS-FORCE — lbt av

x 4.448 =	Newtons (N)
x 0.4536 =	Kilograms-force (kgf)

POUNDS — lb av.

x 453.6 =	Grams (g)
x 16 =	Ounces (oz) av
x 256 =	Drams (dr) av
x 7000 =	Grains (gr)
x 5×10^{-4} =	Tons (ton) short
x 1.2153 =	Pounds (lb) troy

POUNDS PER CUBIC FOOT

x 7000 =	Grams/cubic ft. (g/ft^3)
x1.6×10^{7} =	Grams/cubic meter (g/m^3)

POUNDS = lb troy

x 373.2 =	Grams (g)
x 12 =	Ounces (oz) troy
x 240 =	Pennyweights (dwt) troy
x 5760 =	Grains (gr)
x 0.8229 =	Pounds (lb) av
x 13.166 =	Ounces (oz) av
x 3.6735×10^{-4} =	Tons (ton) long
x 4.1143×10^{-4} =	Tons (ton) short
x 3.7324×10^{-4} =	Tonnes (t) metric tons

POUNDS-MASS OF WATER AT 60°F

x 453.98 =	Cubic centimeters (cm^3)
x 0.45398 =	Liters (l)
x 0.01603 =	Cubic feet (ft^3)
x 27.70 =	Cubic inches (in^3)
x 0.1199 =	U.S. gallons (U.S. gal)

POUNDS OF WATER PER MINUTE AT 60°F

x 7.576 =	Cubic centimeters per second (cm^3/s)
x 2.675×10^{-4} =	Cubic feet per second (cfs)

POUNDS PER CUBIC FOOT — lb/ft^3

x 16.018 =	Kilograms per cubic meter (kg/m^3)
x 0.016018 =	Grams per cubic centimeter (g/cm^3)
x 5.787×10^{-4} =	Pounds per cubic inch (lb/in^3)

KILOPASCALS — kPa

x 10^3 =	Pascals (Pa) or newtons per square meter (N/m^2)
x 0.1450 =	Pounds-force per square inch
x 0.010197 =	Kilograms-force per square centimeter (kg/cm^2)
x 0.2953 =	Inches of mercury (in Hg) at 32°F
x 0.3351 =	Feet of water (ft H_2O) at 68°F
x 4.021 =	Inches of water (in H_2O) at 68°F

KILOWATTS — kW

x 4.425×104 =	Foot-pounds-force per minute ($ft \cdot lb/min$)
x 737.6 =	Foot-pounds-force per second ($ft \cdot lbf/s$)
x 56.90 =	British thermal units per minute (Btu/min)
x 14.33 =	Kilocalories per minute (kcal/min)
x 1.3410 =	Horsepower (hp)

KILOWATT-HOURS — $kW \cdot h$

x 3.6×10^{6} =	Joules (J)
x 2.655×10^{6} =	Foot-pounds-force ($ft \cdot lbf$)
x 3413 =	British thermal units (Btu)
x 860 =	Kilocalories (kcal)
x 3.671×10^{5} =	Kilogram-force meters ($kgf \cdot m$)
x 1.3410 =	Horsepower-hours ($hp \cdot h$)

KNOTS — kn (International)

x 0.5144 =	Meters per second (m/s)
x 1.151 =	Miles per hour (mph)

LITERS — l

x 1000 =	Cubic centimeters (cm^3)
x 0.035315 =	Cubic feet (ft^3)
x 61.024 =	Cubic inches (in^3)
x 1.308×10^{3} =	Cubic yards (yd^3)
x 0.2642 =	U.S. gallons (U.S. gal)
x 0.2200 =	Imperial gallons (imp gal)

LITERS PER MINUTE — l/mln

x 0.01667 =	Liters per second (l/s)
x 5.885×10^{-4} =	Cubic feet per second (cfs)
x 4.403×10^{-3} =	U.S. gallons per second (U.S. gals)
x 3.666×10^{-3} =	Imperial gallons per second (imp gal/s)

LITERS PER SECOND — l/s

x 10^{-3} =	Cubic meters per second (m^3/s)
x 3.600 =	Cubic meters per hour (m^3/h)
x 60 =	Liters per minute (l/min)
x 15.85 =	U.S. gallons per minute (U.S. gpm)
x 13.20 =	Imperial gallons per minute (imp gpm)

MEGAPASCALS — MPa

x 10^6 =	Pascals (Pa) or newtons per square meter (N/m^2)
x 10^3 =	Kilopascals (kPa)
x 145.0 =	Pounds-force per square inch (psi)
x 0.1020 =	Kilograms-force per square millimeter (kgf/mm^2)

METERS — m

x 3.281 =	Feet (ft)
x 39.37 =	Inches (in)
x 1.0936 =	Yards (yd)

METERS PER MIN — m/min

x 1.6667 =	Centimeters per second (cm/s)
x 0.0600 =	Kilometers per hour (km/h)
x 3.281 =	Feet per minute (ft/min)
x 0.05468 =	Feet per second (ft/s)
x 0.03728 =	Miles per hour (mph)

METERS PER SECOND — m/s

x 3.600 =	Kilometers per hour (km/h)
x 0.0600 =	Kilometers per minute (km/min)
x 196.8 =	Feet per minute (ft/min)
x 3.281 =	Feet per second (ft/s)
x 2.237 =	Miles per hour (mph)
x 0.03728 =	Miles per minute (mi/min)

MICROMETERS — um (micron)

x 0.000001 =	Meters (m)

MILES — mi

x 1.6093 x 10^3 =	Meters (m)
x 1.6093 =	Kilometers (km)
x 5280 =	Feet (ft)
x 1760 =	Yards (yd)

MILES PER HOUR — mph

x 44.70 =	Centimeters per second (cm/s)
x 1.6093 =	Kilometers per hour (km/h)
x 26.82 =	Meters per minute (m/min)
x 88 =	Feet per minute (ft/min)
x 1.4667 =	Feet per second (ft/s)
x 0.8690 =	International knots (kn)

MILES PER MINUTE — ml/min

x 1.6093 =	Kilometers per minute (km/min)
x 2682 =	Centimeters per second (cm/s)
x 88 =	Feet per second (ft/s)
x 60 =	Miles per hour (mph)

MINUTES, ANGULAR — (')

x 2.909 x 10^{-4} =	Radians (rad)

NEWTONS — N

x 0.10197 =	Kilograms-force (kgf)
x 0.2248 =	Pounds-force (lbf)
x 7.233 =	Poundals
x 10^5 =	Dynes

OUNCES — oz av

x 28.35 =	Grams (g)
x 2.835 x 10^{-5} =	Tonnes (t) metric ton
x 16 =	Drams (dr) av x 437.5
x 0.06250 =	Pounds (lb) av
x 0.9115 =	Ounces (oz) troy
x 2.790x10^{-5} =	Tons (ton) long

OUNCES — oz troy

x 31.103 =	Grams (g)
x 480 =	Grains (gr)
x 20 =	Pennyweights (dwt) troy
x 0.08333 =	Pounds (lb) troy
x 0.06857 =	Pounds (lb) av.
x 1.0971 =	Ounces (oz) av.

OUNCES — oz U.S. fluid

x 0.02957 =	Liters (l)
x 1.8046 =	Cubic inches (in)

OUNCES-FORCE PER SQUARE INCH — ozf/in^2

x 43.1 =	Pascals (Pa)
x 0.06250 =	Pounds-force per square inch (psi)
x 4.395 =	Grams-force per square centimeter (gf/cm^2)

PARTS PER MILLION BY MASS — mass (weight) in water

x 0.9991 =	Grams per cubic meter (g/m^3) at 15°C
x 0.0583 =	Grains per U.S. gallon (gr/U.S. gal) at 60°F
x 0.0700 =	Grains per imperial gallon (gr/imp gal) at 62°F
x 8.328 =	Pounds per million U.S. gallons at 60°F

PASCALS — Pa

x 1 =	Newtons per square meter (N/m^2)
x 1.450 x 10^{-4} =	Pounds-force per square inch (psi)
x 1.0197 x 10^{-5} =	Kilograms-force per square centimeter (kg/cm^2)
x 10^{-3} =	Kilopascals (kPa)

PENNYWEIGHTS — dwt troy

x 1.5552 =	Grams (g)
x 24 =	Grains (gr)