Formula/Conversion Table
for Water Treatment and Water Distribution

Measurement Conversion	Measurement Conversion	Measurement Conversion	Measurement Conversion
1 ft. = 12 in.	1 MGD = 1.55 cfs	1 grain / gal = 17.1 mg/L	1 min = 60 sec
1 yd. = 3 ft.	1 cu. yd. = 27 cu. ft.	1 gm = 1000 mg	1 hour = 60 min
1 m = 3.28 ft.	1 cu. ft. = 7.48 gal	1 kg = 1000 gm	1 day = 1440 min
1 mi = 5280 ft.	1 gal = 8.34 lbs	1 liter = 1000 ml	1% = 10,000 mg/L
1 sq. ft. = 144 sq. in.	1 cu. ft. = 62.4 lbs	1 gal = 3.785L	1 mg/l = 1 ppm
1 acre = 43,560 sq. ft.	1 kg = 2.2 lbs	1 psi = 2.31 ft. of water	1 hp= 0.746 kW
1 acre-ft. = 43,560 cu. ft.	1 lb. = 454 gm	1 ft. water = 0.433 psi	1 hp = 33,000 ft. lbs/min
1 acre-ft. = 325,829 gal		1 in Mercury = 1.133 ft. of water	1kW = 1,000 W

L = Length   B = Base   W = Width   H = Height   R = Radius   D = Diameter $\pi = 3.14$

Alkalinity

Phenolphthalein Alkalinity, as mg $CaCO_3$/L = $\frac{\text{(Titrant Volume A, ml)(Acid Normality)(50,000)}}{\text{Sample Volume, ml}}$

Total Alkalinity, as mg $CaCO_3$/L = $\frac{\text{(Titrant Volume B, ml)(Acid Normality)(50,000)}}{\text{Sample Volume, ml}}$

Alkalinity Relationships: Alkalinity, mg/l as $CaCO_3$

Result of Titration	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Concentration as $CaCO_3$
P = 0	0	0	T
P < ½ T	0	2P	T – 2P
P = ½ T	0	2P	0
P > ½ T	2P – T	2(T – P)	0
P = T	T	0	0

Key: P – phenolphthalein alkalinity; T – total alkalinity

Area, Circumference and Volume

Area, sq ft

Circle: $A = \pi \times R^2$ or $A = 0.785 \times D^2$

Cylinder (total outside surface area): $A = (2 \times \pi \times R^2) + \pi \times D \times H$ or $A = (2 \times 0.785 \times D^2) + (\pi \times D \times H)$

Rectangle: $A = L \times W$

Triangle: $A = ½ \times B \times H$

Circumference, ft

Circle, ft = $\pi \times D$

Rectangle, ft = $2 \times L + 2 \times W$

Volume, cu ft:

Cone: $V = 1/3 \times 0.785 \times D^2 \times H$ or $V = 1/3 \times \pi \times R^2 \times H$

Cylinder: $V = \pi \times R^2 \times H$ or $V = 0.785 \times D^2 \times H$

Rectangle: $V = L \times W \times H$

Average (arithmetic mean) = $\frac{\text{Sum of All Terms or Measurements}}{\text{Number of Terms or Measurements}}$

Annual Running Average = $\frac{\text{Sum of All Averages}}{\text{Number of Averages}}$

Chemical Feed, Mixing and Solution Strengths

Chemical Feed, lbs/day = (Dry Chemical Feeder)

$$\frac{(\text{Dry Chemical Collected, gm})(60\ \text{min/hr})(24\ \text{hr/day})}{(454\ \text{gm/lb})(\text{Time, min})}$$

Chemical Feed, lbs/day =

$$\frac{(\text{Polymer Feeder) Polymer Conc, mg/l})(\text{Volume Pumped, ml})(60\ \text{min/hr})(24\ \text{hr/day})}{(\text{Time Pumped, min})(1{,}000\ \text{mg/l})(1{,}000\ \text{mg/gm})(454\ \text{gm/lb})}$$

Chemical Feed Pump Setting, % Stroke =

$$\frac{(\text{Desired Flow})(100\%)}{\text{Maximum Flow}}$$

Chemical Feed Pump Setting, mL/minute =

$$\frac{(\text{Flow, MGD})(\text{Dose, mg/L})(3.785\ \text{L/gal})(1{,}000{,}000\ \text{gal/MG})}{(\text{Liquid, mg/ml})(24\ \text{hr/day})(60\text{min/hr})}$$

Chemical Flow, gpm =

$$\frac{\text{Volume Pumped, gal}}{(\text{Pumping Time, hr})(60\ \text{min/hr})}$$

Dry Polymer, lbs = (Water, lbs) / ((100 / polymer %) -1)

Feeder Setting, % =

$$\frac{(\text{Desired Feed Rate, lbs/day})(100\%)}{(\text{Maximum Feed Rate, lbs/day})} \quad \text{or} \quad \frac{(\text{Desired Feed Rate, gph})(100\%)}{\text{Maximum Feed Rate, gph}}$$

Hypochlorite Strength, % =

$$\frac{(\text{Chlorine Required, lbs})(100\%)}{(\text{Hypochlorite Solution Needed, gal})(8.34\ \text{lbs/gal})}$$

Liquid Polymer, gal =

$$\frac{(\text{Polymer Solution, \%})(\text{gal of solution})}{\text{Liquid Polymer, \%}}$$

Mixture Strength, % =

$$\frac{(\text{Amount1, gals})(\text{Strength 1, \%}) + (\text{Amount 2, gals})(\text{strength 2, \%})}{(\text{Amount 1, gals}) + (\text{Amount 2, gals})}$$

Polymer Strength, % =

$$\frac{(\text{Dry Polymer, lbs})(100\%)}{(\text{Dry Polymer, lbs + Water, lbs})} \quad \text{or} \quad \frac{(\text{Weight of Solute, lbs})(100\%}{\text{Weight of Solution}}$$

Water, lbs =

$$\frac{(\text{Dry Polymer, lbs})(100\%) - \text{Dry polymer, lbs}}{\text{Polymer \%}}$$

Water added, gal =

$$\frac{(\text{hypo, gal})(\text{hypo,\%}) - (\text{hypo, gal})(\text{desired hypo, \%})}{\text{Desired hypo, \%}}$$

Demineralization

Membrane Area, sq ft = (Number of Vessels)(Number of Elements/Vessel)(Surface Area/Element)

Average Flux Rate, GFD = (flow through membranes)

$$\frac{\text{Permeate Flow, gpd}}{\text{Membrane Area, sq ft}}$$

Mineral Rejection, % =

$$\left[1 - \frac{\text{Product Concentration (TDS), mg/l}}{\text{Feedwater Concentration (TDS), mg/l}}\right] \times 100\%$$

Recovery, % =

$$\frac{(\text{Product Flow, mgd})(100\%)}{(\text{Feed Flow, mgd})}$$

Detention Time

Detention Time (days)=

$$\frac{\text{Volume, gallons}}{\text{Flow, gpd}}$$

Note: For detention time in hours multiply by 24hr/day and for detention time in minutes multiply by 1440 min/day

Disinfection

Chlorine Demand, mg/L = Chlorine Dosage, mg/L – Chlorine Residual, mg/L

Chlorine Dosage, mg/L = Chlorine Demand, mg/L + Chlorine Residual, mg/L

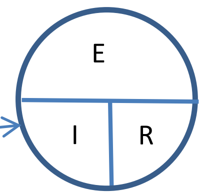
Chlorine Residual, mg/L = Chlorine Dosage, mg/L – Chlorine Demand, mg/L

CT calculation, time = (Disinfectant Residual Concentration, mg/L)(Time) Units must be compatible

Electrical

$$\text{Amps (I)} = \frac{\text{Volts (E)}}{\text{Ohms (R)}}$$

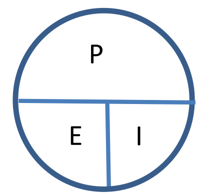
Electromotive Force (E.M.F.), volts = (Current, amps)(Resistance, ohms) or E = I x R



$$\text{Power, kilowatts (3 phase AC circuit)} = \frac{\text{(E, volts)(I, amps)(Power Factor)(1.73)}}{\text{1,000 watts/kilowatt}}$$

$$\text{Power, kilowatts (single phase AC circuit)} = \frac{\text{(E, volts)(I, amps)(Power Factor)}}{\text{1,000 watts/kilowatt}}$$

Power, watts (DC circuit) = (E, volts)(I, amps) or P = E x I

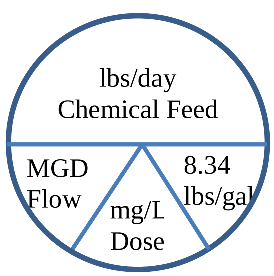


$$\text{Power Output, horsepower} = \frac{\text{(Power Input, kilowatts)(Efficiency, \%)}}{\text{(0.746 kilowatt/horsepower)(100\%)}}$$

Power Requirements, kW-hr = (Power, kilowatts)(Time, hours)

Feed Rate

$$\text{Feed Rate, lbs/day} = \frac{\text{(Dosage, mg/L)(Flow, MGD)(8.34 lbs/gal)}}{\text{(Purity, as a decimal)}}$$



Davidson Pie Chart

- To find the quantity above the horizontal line: multiply the pie wedges below the line together and divide by the purity, as a decimal (i.e., 65% = 0.65).
- To solve for one of the pie wedges below the horizontal line: cover that pie wedge then divide the remaining pie wedges into the quantity above the horizontal line and multiply by the purity, as a decimal (i.e., 65% = 0.65).
- The given units must match the units shown in the pie wheel.

Filtration

$$\text{Backwash Rise Rate, in/min} = \frac{\text{(Backwash Rate, gpm/sq. ft.)(12 in/ft)}}{\text{(7.48 gal/cu. ft.)}}$$

Backwash Pumping Rate, gal/min = (Backwash Rate, gpm/sq. ft.)(Filter Surface Area, sq. ft.)

Backwash Water Required, gal = (Backwash Flow, gpm)(Backwash Time, min)

$$\text{Backwash Water Used, \%} = \frac{\text{(Backwash Water, gal)(100\%)}}{\text{Water Filtered, gal.}}$$

$$\text{Drop Velocity (V), ft/min} = \frac{\text{Water Drop in Filter, ft}}{\text{Time to Drop, min}}$$

$$\text{Filtration Rate or Backwash Rate, GPM/sq. ft.} = \frac{\text{Flow, GPM}}{\text{Filter Surface Area, sq. ft.}}$$

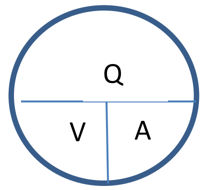
$$\text{Hydraulic or Surface Loading Rate, gpd/sq ft} = \frac{\text{Total Flow Applied, gpd}}{\text{Surface Area, sq ft}}$$

$$\text{Unit Filter Run Volume, gal/sq. ft.} = \frac{\text{Volume Filtered, gal}}{\text{Filter Surface Area, sq. ft.}}$$

Unit Filter Run Volume, gal/sq. ft. = (Filtration Rate, GPM/sq. ft.)(Filter Run, hr)(60 min/hr)

Flow Rates and Velocity (pipe line, channel or stream)

Flow Rate, cfs = (Area, sq. ft.)(Velocity, ft/sec) or Q = V x A



Where:
Q = flow rate, cfs
V = velocity, fps
A = area, ft^2

Flow Rate, gpm = (Area, sq. ft.)(Velocity, ft/sec)(7.48 gal/cu ft)(60 sec/min) or Q = V x A x 7.48 x 60

$$\text{Velocity, fps} = \frac{\text{Flow rate, cfs}}{\text{Area, sq ft}} \quad \text{or} \quad \frac{\text{Distance, ft}}{\text{Time, seconds}}$$

$$\text{Reduction in Flow, \%} = \frac{\text{(Original Flow – Reduced Flow)(100\%)}}{\text{Original Flow}}$$

Fluoridation

$$\text{Feed Rate, lbs/day} = \frac{\text{(Dosage, mg/L)(Flow, MGD)(8.34 lbs/gal)}}{\text{(Fluoride solution, as a decimal)(Purity, as a decimal)}}$$

$$\text{Feed Rate, gpd} = \frac{\text{Feed Rate, lbs/day}}{\text{Chemical solution, lbs/gal}}$$

$$\text{Feed Rate, lbs/day} = \frac{\text{Fluoride, lbs/day}}{\text{Fluoride, lbs / lb of commercial chemical}}$$

$$\text{Fluoride ion purity, \%} = \frac{\text{(Molecular Weight of Fluoride)(100\%)}}{\text{Molecular Weight of Compound}}$$

$$\text{Portion of Fluoride} = \frac{\text{(Commercial Chemical Purity, \%)(Fluoride ion, \%)}}{\text{(100\%) (100\%)}}$$

Flushing Time

$$\text{Flushing Time, sec} = \frac{\text{Volume, cu ft}}{\text{Flow, cfs}} \quad \text{or} \quad \frac{\text{(Length of Pipeline, ft)(Number of Flushing Volumes)}}{\text{(Velocity, ft/sec)}}$$

Laboratory

$$\text{Dilute to ml} = \frac{\text{(Actual Weight, gm)(1,000 ml)}}{\text{(desired Weight, gm)}}$$

Langelier Index (L.I.) = pH -pHs

Leakage and Pressure Testing Pipelines

$$\text{Leakage, gpd} = \frac{\text{Volume, gal}}{\text{Time, days}}$$

$$\text{AC or Ductile Iron Pipe, gpd/mi-in} = \frac{\text{Leak Rate, gpd}}{(\text{length, mi})(\text{Diameter, in})}$$

$$\text{Plastic pipe, gph/100 joints} = \frac{\text{Leak Rate, gph}}{(\text{Number of Joints}) / (\text{100 Joints})}$$

Test Pressure, psi = Normal Pressure + 50% or 150psi whichever is greater

Loading

$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Total Flow, gpd}}{\text{Length of Weir, ft}}$$

Parts per million

$$\text{ppm} = \text{mg/l} = \frac{\text{Pounds of Chemical, lbs}}{(\text{8.34 lbs/gal})(\text{gallons, MG})}$$

Pressure and Head

Head (Height of Water), ft = (Pressure, psi)(2.31 ft / psi) or $\text{Head (Height of Water)} = \frac{\text{Pressure, psi}}{\text{0.433 psi/ft}}$

$\text{Pressure, psi} = \frac{\text{Height, ft}}{\text{2.31 ft/psi}}$ or Pressure, psi = Height, ft x 0.433 psi/ft

Pumps and Motors

$$\text{Brake (bhp)} = \frac{(\text{Flow, GPM})(\text{Head, ft})}{(3{,}960)(\text{Decimal Pump Efficiency})}$$

$$\text{Motor (mhp)} = \frac{(\text{Flow, GPM})(\text{Head, ft})}{(3{,}960)(\text{Decimal Pump Efficiency})(\text{Decimal Motor Efficiency})}$$

$$\text{Water (whp)} = \frac{(\text{Flow, GPM})(\text{Head, ft})}{3{,}960}$$

$$\text{Pumping Rate, GPM} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

Total Dynamic Head, ft = Static Head, ft + Discharge Head, ft + Friction Losses, ft

$$\text{Wire-to-Water Efficiency, \%} = \frac{(\text{Water Horsepower, HP})(100\%)}{\text{Power Input, (Brake HP or Motor HP)}}$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{(\text{Flow, gpm})(\text{Total Dynamic Head, ft})(100\%)}{(\text{Voltage, volts})(\text{Current, amps})(5.308)}$$

$$\text{Kilowatt- hr/day} = (\text{Motor, HP}) \; \frac{\text{x 24 hr}}{\text{day}} \; \text{x} \; \frac{\text{0.746 kW}}{\text{HP}}$$

Cost, \$/day = Kilowatt-hr/day x cost, \$/kWh

Softening Processes

Hardness

Total Hardness, mg/l as $CaCO_3$ = Calcium Hardness, mg/l as $CaCO_3$ + Magnesium Hardness, mg/l as $CaCO_3$
= (2.5)(Ca, mg/l) + (4.12)(Mg, mg/l)

If alkalinity is greater than total hardness:
Carbonate Hardness, mg/l as $CaCO_3$ = Total Hardness, mg/l as CaCO3 and
Noncarbonate Hardness, mg/l as $CaCO_3$ = 0

If alkalinity is less than total hardness:
Carbonate Hardness, mg/l as $CaCO_3$ = Alkalinity, mg/l as $CaCO_3$ and
Noncarbonate Hardness, mg/l as $CaCO_3$ = Total Hardness Removed, mg/l as $CaCO_3$ – Alkalinity removed, mg/l as $CaCO_3$

Lime Softening - If hydrated lime ($Ca(OH)_2$) is used instead of quicklime (CaO), substitute 74 for 56 in equations below.

$$\text{Lime Feed, mg/l} = \frac{(A + B + C + D) \times 1.15}{\text{Purity of Lime, as a decimal}}$$

A = Carbon dioxide (CO_2) in source water: mg/l as CO_2 x (56/44)
B = Bicarbonate alkalinity removed in softening: source water, mg/l as $CaCO_3$ – softened water, mg/l as $CaCO_3$ x (56/100)
C = Hydroxide alkalinity in softener effluent: mg/l as $CaCO_3$ x (56/100)
D = Magnesium removed in softening: source water, mg/l as Mg^{2+} – softened water, mg/l as Mg^{2+} x (56/24.3)

Excess Lime, mg/l = (A + B + C + D)(0.15)

Soda Ash: dosage to remove noncarbonated hardness
Soda Ash (Na_2CO_3) Feed, mg/l = (Noncarbonate Hardness, mg/l as $CaCO_3$)(106/100)

Carbon Dioxide: dosage to recarbonate
Total CO_2 Feed, mg/l = (excess lime, mg/l)(44/56) + (Mg^{2+} residual, mg/l)(44/58.3)

Feeder Setting, lbs/day = (Flow, MGD)(Dose, mg/l)(8.34 lbs/gal)

$$\text{Feed Rate, lbs/min} = \frac{\text{Feeder Setting, lbs/day}}{(60\text{ min/hr})(24\text{ hr/day})}$$

Ion Exchange Softening

$$\text{Hardness, grains/gallon} = \frac{(\text{Hardness, mg/l})(1\text{ grain/gallon})}{17.1\text{ mg/l}}$$

Exchange Capacity, grains = (Media Volume, cu ft)(Removal Capacity, grains/cu ft

$$\text{Water Treated, gal} = \frac{\text{Exchange Capacity, grains}}{\text{Hardness Removed, grains/gallon}}$$

$$\text{Operating Time, hr} = \frac{\text{Water Treated, gal}}{(\text{Avg Daily Flow, gpm})(60\text{ min/hr})}$$

Salt Needed for Regeneration, lbs Salt Required, lbs/1,000 grains)(Hardness Removed, grains

$$\text{Brine, gal} = \frac{\text{Salt Needed, lbs}}{\text{Salt Solution, lbs/gal of brine}}$$

$$\text{Bypass Flow, gpd} = \frac{(\text{Total Flow, gpd})(\text{Finished Water Hardness, gpg})}{\text{Source Water Hardness, gpg}}$$

$$\text{Bypass Water, gal} = \frac{(\text{Softener Capacity, gal})(\text{Bypass Flow, gpd})}{\text{Softener Flow, gpd}}$$

Total Flow, gal = Softener Capacity, gal + Bypass Water, gal

Temperature

Degrees Celsius =: $[(°F - 32)(^5/_9)]$ or $[(°F - 32)(0.555)$ or $\frac{(°F - 32)}{1.8}$

Degrees Fahrenheit = $[(°C)(^9/_5) + 32]$ or $[(°C)(1.8) + 32]$

Turbidity

Removal Percentage, % = $\frac{\text{(Influent Turbidity – Effluent Turbidity)(100\%)}}{\text{Influent Turbidity}}$

Water Production

Gallons/Capita/Day = $\frac{\text{Volume of Water Produced, gpd}}{\text{Population}}$

Abbreviations:

Abbreviations	Types of Measurement	Abbreviations	Measurement Volumes
cfs	Cubic feet per second	m	Meter
DO	Dissolved oxygen	mg	Milligrams
ft	Feet	mg/L	Milligrams per liter
fps	Feet per second	lbs	Pounds
GFD	Gallons per day per square foot	MGD	Million gallons per day
gm	Grams	mL	Milliliter
gpd	Gallons per day	ppb	Parts per billion
gpg	Grains per gallon	ppm	Parts per million
gpm	Gallons per minute	psi	Pounds per square inch
gph	Gallons per hour	Q	Flow
gr	Grains	SS	Settleable solids
hp	Horsepower	TTHM	Total trihalomethanes
in	Inch	TOC	Total organic carbon
kg	Kilogram	TSS	Total suspended solids
kW	Kilowatt	VS	Volatile solids
kWh	Kilowatt-hour	W	Watt