Formula/Conversion Table
for Water Treatment Plant and Water Distribution Systems

1 foot = 12 inches	1 MGD = 1.55 cfs	1 grain / gal = 17.1 mg/L	1 minute = 60 seconds
1 yard = 3 feet	1 cu. yd. = 27 cu. ft.	1 gram = 1,000 mg	1 hour = 60 minutes
1 meter = 3.28 feet	1 cu. ft. = 7.48 gal	1 kg = 1,000 gram	1 day = 1,440 min
1 mile = 5,280 feet	1 gal = 8.34 lbs	1 liter = 1,000 ml	1% = 10,000 mg/L
1 sq. ft. = 144 sq. in.	1 cu. ft. = 62.4 lbs	1 gal = 3.785 liters	1 mg/l = 1 ppm
1 acre = 43,560 sq. ft.	1 kg = 2.2 lbs	1 psi = 2.31 ft. of water head	1 hp= 0.746 kW
1 acre-ft. = 43,560 cu. ft.	1 lb. = 454 g	1 ft. of water head = 0.433 psi	1 hp = 33,000 ft. lbs/min
1 acre-ft. = 325,829 gallons			1kW = 1,000 Watts

Legend: L = length W = width H = height R = radius D = diameter π = 3.14 g = gram

Alkalinity Concepts

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

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

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

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

Key: P – phenolphthalein alkalinity; T – total alkalinity

Area, Circumference and Volume

Area, square feet (ft^2)

Circle: $A = 3.14 \times R^2$ *or* $A = 0.785 \times D^2$

Cylinder, (total outer surface area): $A = (2 \times 3.14 \times R^2) + 3.14 \times D \times H$ *or* $A = (2 \times 0.785 \times D^2) + (3.14 \times D \times H)$

Cylinder (pipe): A = 3.14 x D x L

Square or Rectangle: A = L x W

Circumference (Perimeter), linear feet

Circle = 3.14 x D

Rectangle = (2 x L) + (2 x W)

Volume, cubic feet (ft^3):

Cylinder: $V = 3.14 \times R^2 \times H$ *or* $V = 0.785 \times D^2 \times H$

Rectangle: V = L x W x H

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

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

Chemical Feed, Mixing and Solution Strengths

Chemical Feed, lbs/day = (Dry Chemical Feeder) $\dfrac{\text{(Dry Chemical, g) (60 min/hr.) (24 hr./day)}}{\text{(454 g/lb.) (Time, min)}}$

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

Chemical feed pump setting, % stroke = $\dfrac{\text{Desired feed flow, gpd}}{\text{Maximum feed flow, gpd}}$ x 100%

Chemical Feed Pump Setting, mL/minute = $\dfrac{\text{(Flow, MGD) (Dose, mg/L) (3.785 L/gal) (1,000,000 gal/MG)}}{\text{(Liquid alum, mg/ml) (1,440 min/day)}}$

Chemical Flow, gpm = $\dfrac{\text{Volume Pumped, gal}}{\text{(Pumping Time, hr) (60 min/hr)}}$

Feeder setting, % = $\dfrac{\text{Desired feed rate, lbs./day}}{\text{Maximum feed rate, lbs./day}}$ x 100% *or* $\dfrac{\text{Desired flow, gpd}}{\text{Maximum flow, gpd}}$ x 100%

Hypochlorite Strength, % = $\dfrac{\text{Chlorine required, lbs/day}}{\text{(Hypochlorite solution needed, gal/day) (8.34 lbs./gal)}}$ x 100%

Lbs. of Chemical = (amount of solution needed, gal) (solution strength, as a decimal) (8.34 lbs/gal)

Liquid Polymer, gal = $\dfrac{\text{(Polymer Solution, \%) (gal of solution)}}{\text{Supplied Liquid Polymer, \%}}$

Mixture Strength, % = $\dfrac{\text{(Amount 1, gals) (Strength 1, \%) + (Amount 2, gals) (strength 2, \%)}}{\text{(Amount 1, gals) + (Amount 2, gals)}}$

Polymer Solution, % = $\dfrac{\text{(Dry Polymer, lbs) (100\%)}}{\text{(Dry Polymer, lbs + Water, lbs)}}$

Water added for hypochlorite sol'n, gal = $\dfrac{\text{(hypo, gal) (hypo,\%) – (hypo, gal) (desired hypo,\%)}}{\text{Desired hypo, \%}}$

Potassium Permanganate Dose, mg/L = (0.2 x Iron content, mg/L) + (2.0 x Manganese content, mg/L)

Demineralization

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

Mineral Rejection, % = $$\left(1 - \frac{\text{Product TDS Concentration, mg/L}}{\text{Feedwater TDS Concentration, mg/L}}\right) \times 100\%$$

Recovery, % = $$\frac{\text{Product Flow, MGD}}{\text{Feed Flow, MGD}} \times 100\%$$

Detention Time

Detention Time, days = $$\frac{\text{Tank Volume, gallons}}{\text{Flow Rate, gal/day}}$$

Note: for detention time in hours, multiply by 24 hrs/day
For detention time in minutes, multiply by 1,440 min/day

Disinfection

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

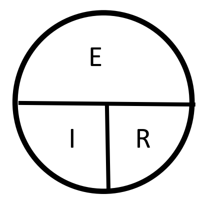
Chlorine Dosage, mg/L = Chlorine Demand, mg/L + Chlorine Residual, mg/L

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

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

Electrical

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

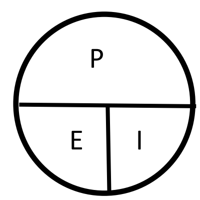


Electromotive Force (EMF), volts = (Current, amps) (Resistance, ohms) *or* E = I x R

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

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 →

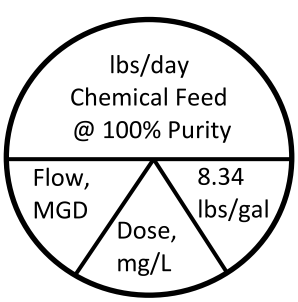


Power Output, horsepower = $$\frac{\text{(Power Input, Kw x Efficiency, \%)}}{\text{0.746 Kw/ Hp}} \times 100\%$$

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

Feed Rate, 100% chlorine

Feed Rate, lbs/day = (Dosage, mg/L) (Flow, MGD) (8.34 lbs/gal)



Using the Davidson Pie Chart

- <u>To find the quantity above the horizontal line:</u> Multiply the 3 pie wedges below the line together. Next, divide by the % purity as a decimal (i.e., 65% = 0.65).
- <u>To solve for one of the pie wedges below the horizontal line:</u> Divide the 2 bottom pie wedges into the quantity of lbs above the horizontal line. Next, multiply by the % purity as a decimal (i.e., 65% = 0.65).
- The given units must match the units shown in the pie wheel.
- Dose = mg/L or PPM

$$\text{Calcium Hypochlorite (CaOCl), lbs.} = \frac{\text{Pure chlorine required, lbs/day}}{\text{CaOCl \% Purity, as decimal}} \times 100\%$$

$$\text{Sodium Hypochlorite (NaOCl), gals.} = \frac{\text{Pure chlorine required, lbs/day}}{\text{(NaOCl \% purity as decimal) (8.34 lbs/gal)}} \times 100\%$$

Filtration

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

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)

$$\text{Backwash Water Used, \%} = \frac{\text{Backwash Water, gal}}{\text{Water Filtered, gal}} \times 100\%$$

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

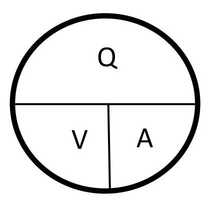
$$\text{Hydraulic or Surface Loading Rate, gpd/sq ft} = \frac{\text{Total Flow Applied, gpd}}{\text{Surface Area, sq ft}}$$

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

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

Flow Rates and Velocity *(pipeline, channel or stream)*

Flow Rate, cfs = (Area, sq. ft.) (Velocity, ft/sec) *or* $Q = V \times A$



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* $Q = V \times A \times 7.48 \times 60$

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

Fluoridation

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

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

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

$$\text{Fluoride Ion Purity, \%} = \frac{\text{Molecular Weight of Fluoride}}{\text{Molecular Weight of Compound}} \times 100\%$$

Flushing Time

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

Laboratory

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

Langelier Saturation Index (L.S.I.) = $pH - pH_S$

Leakage and Pressure Testing Pipelines

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

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

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

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

Loading

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

Parts per million (PPM) or milligrams per liter, (mg/L)

$$\text{Dosage, PPM or mg/L} = \frac{\text{Pounds of Chemical, lbs}}{(\text{Water Volume, MG})(8.34\text{ lbs/gal})}$$

Pressure and Head

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

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

Pumps, Motors and Horsepower

$$\text{Water Horsepower (WHP)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{3{,}960}$$

$$\text{Brake Horsepower (BHP)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)(\text{Pump Efficiency as decimal})}$$

$$\text{Motor Horsepower (MHP)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)(\text{Pump Efficiency as decimal})(\text{Motor Efficiency as decimal})}$$

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

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

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

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

Kilowatt-hr/day = (Motor, Hp) (Motor Run Time, hr/day) (0.746 kW/Hp)

Softening Processes

Hardness

Total Hardness, mg/l as $CaCO_3$ = Calcium Hardness, mg/l as $CaCO_3$ + Magnesium Hardness, mg/l as $CaCO_3$

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

If alkalinity is less than total hardness:
Carbonate Hardness, mg/l as $CaCO_3$ = Amount of total hardness up to the Total Alkalinity, mg/l as $CaCO_3$, or
Noncarbonate Hardness, mg/l as $CaCO_3$ = Total Hardness, mg/l as $CaCO_3$ – Total Alkalinity, mg/l as $CaCO_3$

Lime / Soda Ash Softening

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

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

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^{2+}, mg/l – softened water Mg^{2+}, mg/l	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)

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

$$\text{Feed Rate, lbs/min} = \frac{\text{Feeder Setting, lbs/day}}{\text{1,440 min/day}}$$

Ion Exchange Softening

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

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

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

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

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

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

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

Temperature Conversions

$$\text{Degrees Celsius, }^{o}\text{C} = (^{o}\text{F} - 32)(0.555) \textit{ or } \frac{(^{o}\text{F} - 32)}{1.8}$$

$$\text{Degrees Fahrenheit, }^{o}\text{F} = (^{o}\text{C} \times 1.8) + 32$$

Turbidity

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

Water Loss

$$\text{Unaccounted For Water, \%} = \frac{(\text{Water Produced, gals} - \text{Water Billed, gals})}{\text{Water Produced, gals}} \times 100\%$$

Water Production

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

Water Treatment Plant % capacity

$$\text{Capacity, \%} = \frac{\text{Average Daily Flow, MGD}}{\text{Plant Design Capacity, MGD}} \times 100\%$$

Abbreviations:

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