### Formula/Conversion Table
for Water Treatment and Water Distribution

<table>
<thead>
<tr>
<th>Measurement Conversion</th>
<th>Measurement Conversion</th>
<th>Measurement Conversion</th>
<th>Measurement Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft. = 12 in.</td>
<td>1 MGD = 1.55 cfs</td>
<td>1 grain / gal = 17.1 mg/L</td>
<td>1 min = 60 sec</td>
</tr>
<tr>
<td>1 yd. = 3 ft.</td>
<td>1 cu. yd. = 27 cu. ft.</td>
<td>1 gm = 1000 mg</td>
<td>1 hour = 60 min</td>
</tr>
<tr>
<td>1 m = 3.28 ft.</td>
<td>1 cu. ft. = 7.48 gal</td>
<td>1 kg = 1000 gm</td>
<td>1 day = 1440 min</td>
</tr>
<tr>
<td>1 mi = 5,280 ft.</td>
<td>1 gal = 8.34 lbs</td>
<td>1 liter = 1000 ml</td>
<td>1% = 10,000 mg/L</td>
</tr>
<tr>
<td>1 sq. ft. = 144 sq. in.</td>
<td>1 cu. ft. = 62.4 lbs</td>
<td>1 gal = 3.785L</td>
<td>1 mg/l = 1 ppm</td>
</tr>
<tr>
<td>1 acre = 43,560 sq. ft.</td>
<td>1 kg = 2.2 lbs</td>
<td>1 psi = 2.31 ft. of water</td>
<td>1 hp = 0.746 kW</td>
</tr>
<tr>
<td>1 acre-ft. = 43,560 cu. ft.</td>
<td>1 lb. = 454 gm</td>
<td>1 ft. water = 0.433 psi</td>
<td>1 hp = 33,000 ft. lbs/min</td>
</tr>
<tr>
<td>1 acre-ft. = 325,829 gal</td>
<td>1 in Mercury = 1.133 ft. of water</td>
<td>1 kW = 1,000 W</td>
<td></td>
</tr>
</tbody>
</table>

### Alkalinity

Phenolphthalein Alkalinity, as mg CaCO₃/L = \( \frac{(\text{Titrant Volume A, ml})(\text{Acid Normality})(50,000)}{\text{Sample Volume, ml}} \)

Total Alkalinity, as mg CaCO₃/L = \( \frac{(\text{Titrant Volume B, ml})(\text{Acid Normality})(50,000)}{\text{Sample Volume, ml}} \)

### Alkalinity Relationships: Alkalinity, mg/l as CaCO₃

<table>
<thead>
<tr>
<th>Result of Titrination</th>
<th>Bicarbonate Alkalinity as CaCO₃</th>
<th>Carbonate Alkalinity as CaCO₃</th>
<th>Hydroxide Alkalinity as CaCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>P = 0</td>
<td>T</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>P &lt; ½ T</td>
<td>T – 2P</td>
<td>2P</td>
<td>0</td>
</tr>
<tr>
<td>P = ½ T</td>
<td>0</td>
<td>2P</td>
<td>0</td>
</tr>
<tr>
<td>P &gt; ½ T</td>
<td>0</td>
<td>2T – 2P</td>
<td>2P – T</td>
</tr>
<tr>
<td>P = T</td>
<td>0</td>
<td>0</td>
<td>T</td>
</tr>
</tbody>
</table>

Key: \( P \) = phenolphthalein alkalinity; \( T \) = total alkalinity

### Area, Circumference and Volume

#### Area, sq ft

- Circle: \( A = \pi \times R^2 \quad \text{or} \quad A = 0.785 \times D^2 \)
- Cylinder (total outside surface area): \( A = (2 \times \pi \times R^2) + \pi \times D \times H \quad \text{or} \quad A = (2 \times 0.785 \times D^2) + (\pi \times D \times H) \)
- Rectangle: \( A = L \times W \)
- Triangle: \( A = \frac{1}{2} \times B \times H \)

#### Circumference, ft

- Circle, \( C = \pi \times D \)
- Rectangle, \( C = 2 \times L + 2 \times W \)

#### Volume, cu ft

- Cone: \( V = \frac{1}{3} \times \pi \times R^2 \times H \quad \text{or} \quad V = 1/3 \times \pi \times R^2 \times H \)
- Cylinder: \( V = \pi \times R^2 \times H \quad \text{or} \quad V = 0.785 \times D^2 \times H \)
- Rectangle: \( V = L \times W \times H \)

### Average (arithmetic mean) =

\[
\text{Sum of All Terms or Measurements} \div \text{Number of Terms or Measurements}
\]

### Annual Running Average =

\[
\text{Sum of All Averages} \div \text{Number of Averages}
\]
**Chemical Feed, Mixing and Solution Strengths**

Chemical Feed, lbs/day =

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

Chemical Feed, lbs/day =

\[
\frac{(\text{Chemical Conc, mg/L})(\text{Volume Pumped, mL})(60 \text{ min/hr})(24 \text{ hr/day})}{(\text{Time Pumped, min})(1,000 \text{ mg/L})(1,000 \text{ mg/gm})(454 \text{ gm/lb})}
\]

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 =

\[
\frac{(\text{Water, lbs})}{((100 / \text{polymer }\%)-1)}
\]

Feeder Setting, % =

\[
\frac{(\text{Desired Feed Rate, lbs/day})(100\%)}{\text{Maximum Feed Rate, lbs/day}}
\]

\text{or}

\[
\frac{(\text{Desired Feed Rate, gph})(100\%)}{\text{Maximum Feed Rate, gph}}
\]

Hypochlorite Strength, % =

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

Liquid Polymer, gal =

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

Mixture Strength, % =

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

Polymer Strength, % =

\[
\frac{(\text{Dry Polymer, lbs})(100\%)}{(\text{Dry Polymer, lbs + Water, lbs})}
\]

\text{or}

\[
\frac{(\text{Weight of Solute, lbs})(100\%)}{\text{Weight of Solution}}
\]

Water, lbs =

\[
\frac{(\text{Dry Polymer, lbs})(100\%)}{\text{Water, lbs}} - \frac{\text{Dry polymer, lbs}}{\text{Polymer \%}}
\]

Water added, gal =

\[
\frac{(\text{hypo, gal})(\text{hypo, }\%)}{(\text{Desired hypo, }\%) - (\text{Desired hypo, }\%)}
\]

\text{Detention Time (Retention Time)}

Detention Time, days =

\[
\frac{(\text{Volume, gallons})}{(\text{Flow, gpd})}
\]

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

\text{Demineralization}

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

Average Flux Rate, GFD =

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

Mineral Rejection, % =

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

Recovery, % =

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

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**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**

- **Amps (I)** = **Volts (E)** / **Ohms (R)**
- **Electromotive Force (E.M.F.), volts** = (Current, amps)(Resistance, ohms) or E = I x R
- **Power, kilowatts (3 phase AC circuit)** = \( \frac{(E, \text{ volts})(I, \text{ amps})(\text{Power Factor})(1.73)}{1,000 \text{ watts/kilowatt}} \)
- **Power, kilowatts (single phase AC circuit)** = \( \frac{(E, \text{ volts})(I, \text{ amps})(\text{Power Factor})}{1,000 \text{ watts/kilowatt}} \)
- **Power, watts (DC circuit)** = (E, volts)(I, amps) or P = E x I
- **Power Output, horsepower** = \( \frac{(\text{Power Input, kilowatts})(\text{Efficiency, %})}{0.746 \text{ kilowatt/horsepower}(100\%)} \)
- **Power Requirements, kW-hr** = (Power, kilowatts)(Time, hours)

**Feed Rate**

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

**Filtration**

- **Backwash Rise Rate, in/min** = \( \frac{\text{Backwash Rate, gpm/sq. ft.}(12 \text{ in/ft})}{(7.48 \text{ gal/cu. ft.})} \)
- **Backwash Pumping Rate, gal/min** = \( \text{Backwash Rate, gpm/sq. ft.}(\text{Filter Surface Area, sq.ft.}) \)
- **Backwash Water Required, gal** = \( \text{Backwash Flow, gpm}(\text{Backwash Time, min}) \)
- **Backwash Water Used, %** = \( \frac{\text{Backwash Water, gal}}{\text{Water Filtered, gal.}}(100\%) \)
- **Drop Velocity (V), ft/min** = \( \frac{\text{Water Drop in Filter, ft}}{\text{Time to Drop, min}} \)
- **Filtration Rate or Backwash Rate, GPM/sq. ft.** = \( \frac{\text{Flow, GPM}}{\text{Filter Surface Area, sq. ft.}} \)
Hydraulic or Surface Loading Rate, gpd/sq ft = \( \frac{\text{Total Flow Applied, gpd}}{\text{Surface Area, sq ft}} \)

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 \( Q = V \times A \)

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

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

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

**Fluoridation**

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

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

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

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

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

**Flushing Time**

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

**Laboratory**

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

Langelier Index (L.I.) = pH - pHₜ
**Leakage and Pressure Testing Pipelines**

Leakage, gpd = Volume, gal / Time, days

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

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

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

**Loading**

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

**Parts per million**

\[ \text{ppm} = \frac{\text{mg/l}}{1} = \frac{\text{Pounds of Chemical, lbs}}{(8.34 \text{ lbs/gal})(\text{gallons, MG})} \]

**Pressure and Head**

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

Pressure, psi = \( \frac{\text{Height, ft}}{2.31 \text{ ft/psi}} \) or Pressure, psi = Height, ft \( \times 0.433 \text{ psi/ft} \)

**Pumps and Motors**

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

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

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

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

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

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

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

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

Cost, $/day = \text{Kilowatt-hr/day} \times \text{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$_3$

*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$_3$ = Alkalinity, mg/L as CaCO$_3$, and Noncarbonate Hardness, mg/L as CaCO$_3$ = Total Hardness, mg/L as CaCO$_3$ – Alkalinity, mg/L as CaCO$_3$

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

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

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 noncarbonate hardness

Soda Ash (Na$_2$CO$_3$) 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)

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

**Ion Exchange Softening**

Hardness, grains/gallon = $(Hardness, \ mg/L)(1 \ grain/gallon)$

17.1 mg/L

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

Water Treated, gal = Exchange Capacity, grains

Hardness Removed, grains/gallon

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

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

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

Bypass Flow, gpd = $(Total \ Flow, \ gpd)(Finished \ Water \ Hardness, \ gpg)$

Source Water Hardness, gpg

Bypass Water, gal = $(Softener \ Capacity, \ gal)(Bypass \ Flow, \ gpd)$

Softener Flow, gpd

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

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**Temperature**

\[
\text{Degrees Celsius} = \left(\frac{(°F - 32)\cdot \frac{5}{9}}{1.8}\right) \quad \text{or} \quad (°F - 32)(0.555) \quad \text{or} \quad \frac{°F - 32}{1.8}
\]

\[
\text{Degrees Fahrenheit} = [(°C)(\frac{9}{5}) + 32] \quad \text{or} \quad [(°C)(1.8) + 32]
\]

**Turbidity**

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

**Water Production**

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

**Abbreviations:**

<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Types of Measurement</th>
<th>Abbreviations</th>
<th>Measurement Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>cfs</td>
<td>Cubic feet per second</td>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved oxygen</td>
<td>mg</td>
<td>Milligrams</td>
</tr>
<tr>
<td>ft</td>
<td>Feet</td>
<td>mg/L</td>
<td>Milligrams per liter</td>
</tr>
<tr>
<td>fps</td>
<td>Feet per second</td>
<td>lbs</td>
<td>Pounds</td>
</tr>
<tr>
<td>GFD</td>
<td>Gallons per day per square foot</td>
<td>MGD</td>
<td>Million gallons per day</td>
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<td>gm</td>
<td>Grams</td>
<td>mL</td>
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<td>Gallons per day</td>
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<td>Grains per gallon</td>
<td>ppm</td>
<td>Parts per million</td>
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<td>gph</td>
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<td>Grains</td>
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<tr>
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<td>Horsepower</td>
<td>TTHM</td>
<td>Total trihalomethanes</td>
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<tr>
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<td>Inch</td>
<td>TOC</td>
<td>Total organic carbon</td>
</tr>
<tr>
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<td>Kilogram</td>
<td>TSS</td>
<td>Total suspended solids</td>
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<tr>
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<td>Kilowatt</td>
<td>VS</td>
<td>Volatile solids</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt-hour</td>
<td>W</td>
<td>Watt</td>
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</tbody>
</table>