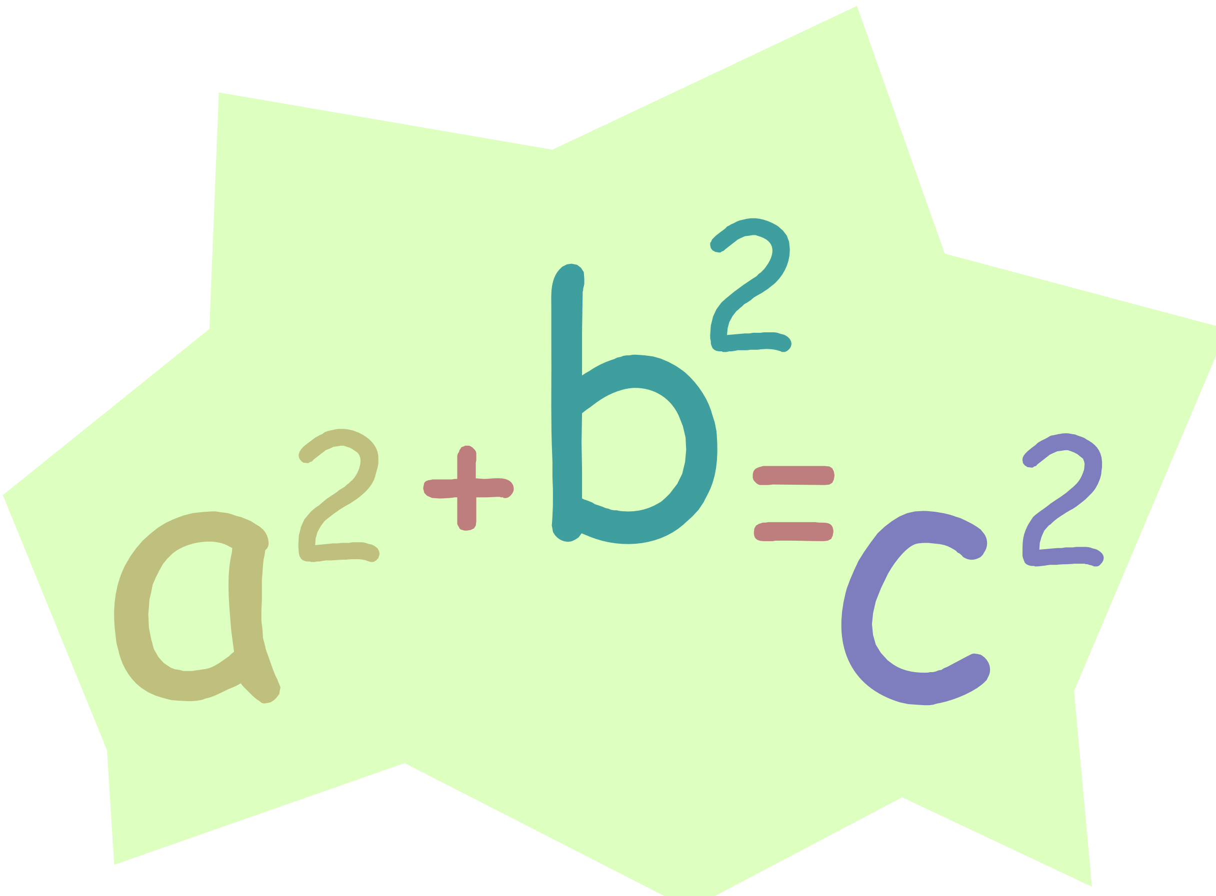
Water Treatment Mathematical Formulas

6th Edition



Fleming Training Center
Murfreesboro, TN
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Conversion Factors

Length

1 yard (yd) .... 3 feet (ft)

1 mile (mi)... 5,280 feet (ft)

Area

1 acre (ac) .... 43,560 square feet (ft^2)

1 square foot (ft^2)....................... 144 square inches (in^2)

Volume

1 ft^3 .... 7.48 gallons (gal)

1 gallon .... 231 cubic inches (in^3)

1 gallon .... 3.785 Liters (L)

1 liter..1,000 milliliters (mL)

1 acre/foot (ac-ft) ....43,560 cubic feet (ft^3)

1 acre-foot (ac-ft) .... 325,828.8 gallons (gal)

Weight and Mass

1 gallon of water .... 8.34 pounds (lbs)

1 cubic foot of water (ft^3)................................... 62.4 lbs

1 pound (lb) .... 453.6 grams (g)

1 kilogram (kg).................................... 1,000 grams (g)

1 gram .... 1,000 milligrams (mg)

1% .... 10,000 milligrams per liter (mg/L)

1 mg/L .... 0.0584 grains per gallon

1 grain per gallon.......................................17.118 mg/L

Pressure and Head

1 foot of head.............. 0.433 pounds per square in (psi)

1 pound per square inch (psi)..............2.31 feet of head

Temperature Conversions

°C .... 0.556 (°F-32°)

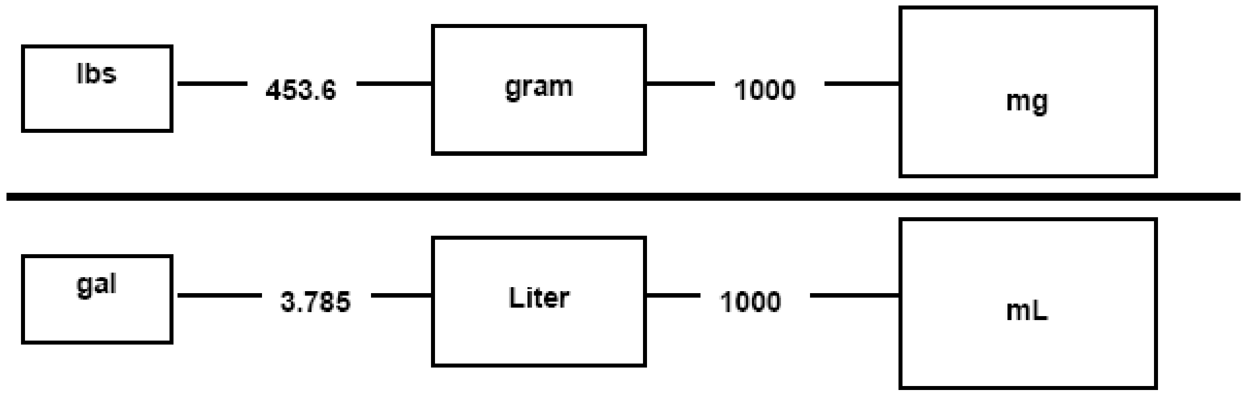
°F...1.8(°C) + 32°

Power

1 Horsepower .... 746 watts

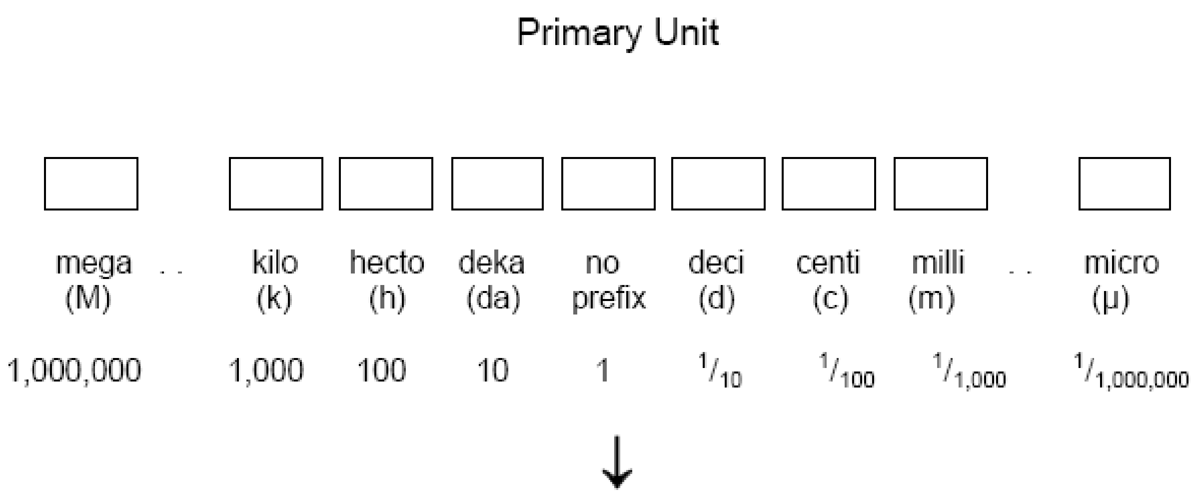
1 Horsepower .... 0.746 kilowatts

Converting lbs/gal to mg/mL



To use this diagram: First, find the box that coincides with the beginning units (i.e. mg/mL). Then, find the box that coincides with the desired ending units (i.e. lbs/gal). The numbers between the starting point and ending point are the conversion factors. When moving from a smaller box to a larger box, multiply by the factor between them. When moving from a larger box to a smaller box, divide by the factor between them. For final number, divide top number by bottom number.

Metric Conversions



meter – linear measurement
liter – volume measurement
gram – weight measurement

Area

Rectangle: $\text{Area, ft}^2 = (\text{Length, ft})(\text{Width, ft})$

Circle: $\text{Area, ft}^2 = (0.785)(\text{Diameter, ft})^2$

Volume

Rectangle, ft^3: $\text{Volume, ft}^3 = (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})$

Cylinder, ft^3: $\text{Volume, ft}^3 = (0.785)(\text{Diameter, ft})^2(\text{Depth or Length, ft})$

Segment of Cylinder, ft^3:

$$\text{Volume, ft}^3 = \left[1.333\,(\text{Height})^2 \sqrt{\frac{\text{Diameter, ft}}{\text{Height, ft}} - 0.608}\right](\text{Length, ft})$$

Wedge:

$$\text{Volume, ft}^3 = \frac{(\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})}{2}$$

Volume, gallons = $\text{Volume, gal} = (\text{Volume, ft}^3)(7.48\text{ga}/\text{ft}^3)$

Flow

$Q = AV$ OR $Q = (\text{Area})(\text{Velocity})$

$$Q\,(\text{Channel}),\ \text{ft}^3/\text{sec} = (\text{Width, ft})(\text{Depth, ft})(\text{Velocity, ft/sec})$$

$$Q\,(\text{Pipeline}),\ \text{ft}^3/\text{sec} = (0.785)(\text{Diameter, ft})^2(\text{Velocity, ft/sec})$$

$$\text{Velocity, ft/sec} = \frac{\text{Flow, ft}^3/\text{sec}}{(0.785)(\text{Diameter, ft})^2}$$

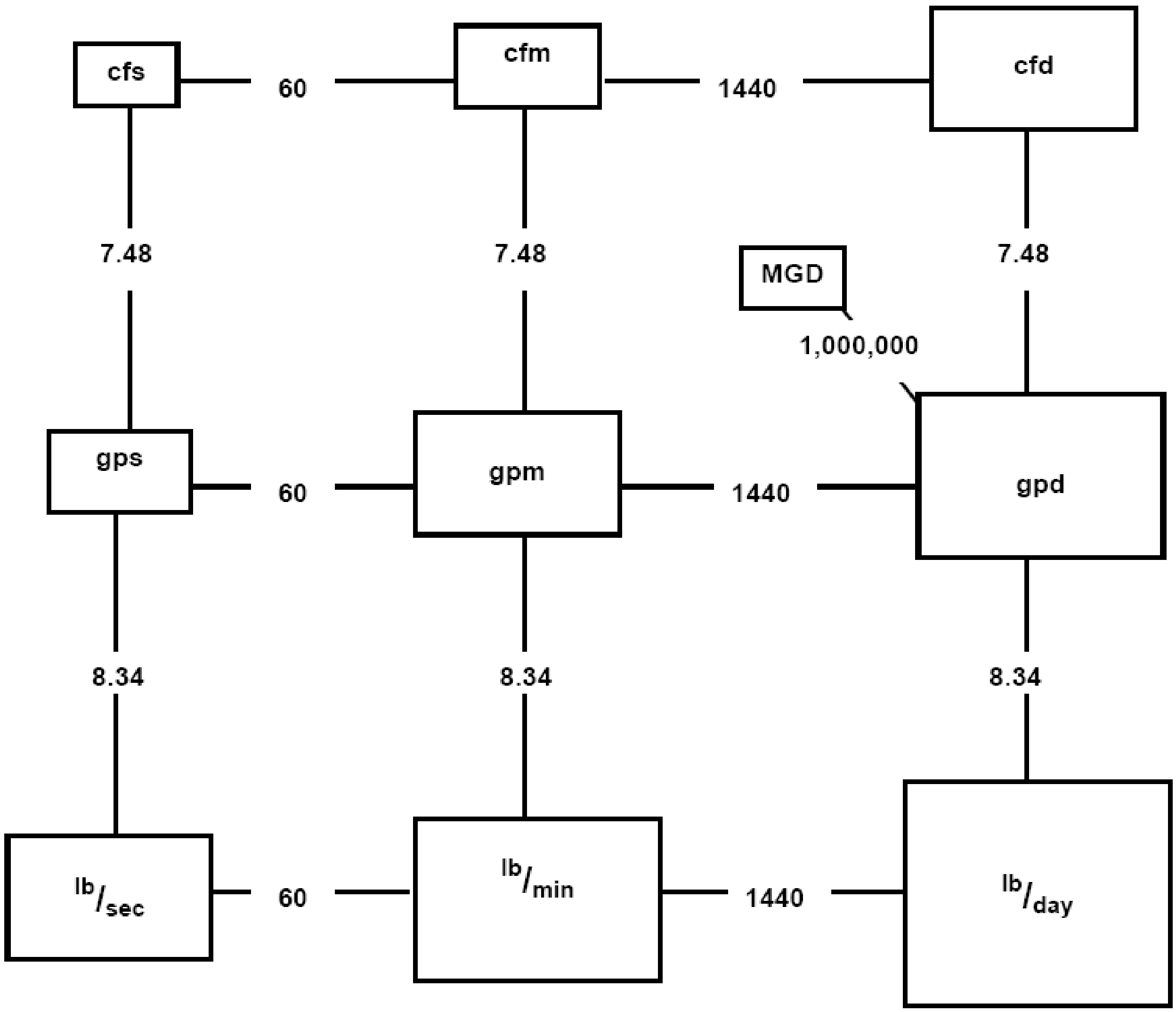
$$\text{Velocity, ft/sec} = \frac{\text{Distance, ft}}{\text{Time, sec}}$$

$$\text{Average Daily Flow, MGD} = \frac{\text{Sum of All Daily Flows, MGD}}{\text{Number of Daily Flows}}$$

$$\text{Annual Average Daily Flow, MGD} = \frac{\text{Sum of All Monthly Average Daily Flows, MGD}}{\text{Number of Monthly Average Daily Flows}}$$

$$\text{Daily Flow, gal/day/capita} = \frac{\text{Water Used, gal/day}}{\text{Total Number of People Served}}$$

Flow Conversions



cfs	=	cubic feet per second	gps	=	gallons per second
cfm	=	cubic feet per minute	gpm	=	gallons per minute
cfd	=	cubic feet per day	gpd	=	gallons per day

To use this diagram: First, find the box that coincides with the beginning units (i.e. gpm). Then, find the box that coincides with the desired ending units (i.e. cfs). The numbers between the starting point and ending point are the conversion factors. When moving from a smaller box to a larger box, multiply by the factor between them. When moving from a larger box to a smaller box, divide by the factor between them.

Dosage

$$\text{Dosage, mg/L} = \frac{\text{Chemical Feed Rate, lb/day}}{(\text{Flow, MGD})\ (8.34\ \text{lbs/gal})}$$

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

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, grams/min})\ (1{,}000\ \text{mg/gram})}{(\text{Flow, gal/min})\ (3.785\ \text{L/gal})}$$

Pounds

$$\text{Chemical Fed, lbs} = (\text{Dose, mg/L})\ (\text{Volume, MG})\ (8.34\ \text{lbs/gal})$$

$$\text{Chemical Fed, lbs} = \frac{(\text{Dose, mg/L})\ (\text{Volume, MG})\ (8.34\ \text{lbs/gal})}{\text{Chemical Purity, \%, expressed as a decimal}}$$

$$\text{Feed Rate, lbs/day} = (\text{Dose, mg/L})\ (\text{Flow, MGD})\ (8.34\ \text{lbs/gal})$$

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

$$\text{Feed Rate, lbs/day} = \frac{(\text{Concentration, mg/mL})(\text{Volume Pumped, mL})\ (1{,}440\ \text{min/day})}{(\text{Time Pumped, min})\ (1{,}000\ \text{mg/g})\ (453.6\ \text{g/lb})}$$

Well Formulas

$$\text{Well Yield, gal/min} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

$$\text{Drawdown, ft} = \text{Pumping Water Level, ft} - \text{Static Water Level, ft}$$

$$\text{Specific Capacity, gal/min/ft} = \frac{\text{Well Yield, gal/min}}{\text{Drawdown, ft}}$$

Power

$$\text{Power, watts} = (\text{Volts})(\text{Amps})$$

$$\text{Amps, single-phase} = \frac{(746\ \text{watts/HP})(\text{Horsepower})}{(\text{Volts})(\text{Efficiency, \%, as decimal})(\text{Power Factor})}$$

$$\text{Amps, three-phase} = \frac{(746\ \text{watts/HP})(\text{Horsepower})}{(1.732)(\text{Volts})(\text{Efficiency, \%, as decimal})(\text{Power Factor})}$$

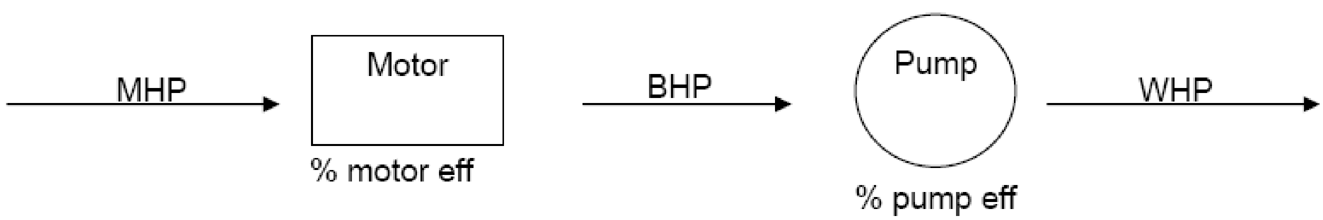
$$\text{Horsepower} = \frac{(\text{Volts})(\text{Amps})}{(746\ \text{watts/HP})}$$

$$\text{Kilowatts, single-phase} = \frac{(\text{Volts})(\text{Amps})(\text{Power Factor})}{1{,}000\ \text{watts/kilowatt}}$$

$$\text{Kilowatts, three-phase} = \frac{(\text{Volts})(\text{Amps})(\text{Power Factor})(1.732)}{1{,}000\ \text{watts/kilowatt}}$$

$$\text{Power Factor} = \frac{\text{Watts}}{(\text{Volts})(\text{Amps})}$$

Pumps



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

$$\text{Pumping Rate, gal/min} = \frac{(\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})(7.48\ \text{gal/ft}^3)}{\text{Time, min}}$$

$$\text{Pumping Rate, gal/min} = \frac{(0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\ \text{gal/ft}^3)}{\text{Time, min}}$$

$$\text{Time to Fill, min} = \frac{\text{Tank Volume, gal}}{\text{Flow Rate, gal/min}}$$

$$\text{Water HP} = \frac{(\text{Flow, gal/min})(\text{Head, ft})}{3960}$$

$$\text{Brake HP} = \frac{(\text{Flow, gal/min})(\text{Head, ft})}{(3960)(\text{Pump Efficiency, \%, expressed as a decimal})}$$

$$\text{Motor HP} = \frac{(\text{Flow, gal/min})\,(\text{Head, ft})}{(3960)\,(\text{Pump Eff., \%, expressed as decimal})\,(\text{Motor Eff., \%, expressed as decimal})}$$

$$\text{Brake HP} = \frac{(\text{Water Horsepower})}{\text{Pump Efficiency, \%, expressed as a decimal}}$$

$$\text{Motor HP} = \frac{(\text{Brake Horsepower})}{\text{Motor Efficiency, \%, expressed as a decimal}}$$

$$\text{Motor Efficiency, \%} = \frac{\text{Brake Horsepower}}{\text{Motor Horsepower}} \times 100\%$$

$$\text{Pump Efficiency, \%} = \frac{\text{Water Horsepower}}{\text{Brake Horsepower}} \times 100\%$$

$$\text{Efficiency, \%} = \frac{\text{Horsepower Output}}{\text{Horsepower Supplied}} \times 100\%$$

$$\text{Overall Efficiency, \%} = \frac{\text{Water Horsepower}}{\text{Motor Horsepower}} \times 100\%$$

$$\text{Wire - to - Water Efficiency, \%} = (\text{Pump Eff., \%, as decimal})\,(\text{Motor Eff., \%, as decimal})\,(100\%)$$

$$\text{Static Head, ft} = \text{Suction Lift, ft} + \text{Discharge Head, ft}$$

$$\text{Static Head, ft} = \text{Discharge Head, ft} - \text{Suction Head, ft}$$

$$\text{Friction Loss, ft} = (0.1)\,(\text{Static Head, ft}) \quad \text{**use this formula in absence of other data}$$

$$\text{Total Dynamic Head, ft} = \text{Static Head, ft} + \text{Friction Losses, ft}$$

$$\text{Cost, \$/hr} = (\text{Motor Horsepower})\,(0.746\ \text{kW/HP})(\text{Cost, \$/kW - hr})$$

Solution Preparation

$$\text{Percent Strength, \% (by weight)} = \frac{\text{Weight of Chemical, lbs}}{(\text{Weight of Water, lbs} + \text{Weight of Chemical, lbs})} \times 100\%$$

$$\text{Concentration, \%} = \frac{\text{Concentration, lbs/gal}}{\text{Density, lbs/gal}} \times 100\%$$

$$(\text{Concentration}_1)\,(\text{Volume}_1) = (\text{Concentration}_2)\,(\text{Volume}_2)$$

$$(\text{Normality}_1)\,(\text{Volume}_1) = (\text{Normality}_2)\,(\text{Volume}_2)$$

$$\text{Chemical, lbs} = \frac{(\text{Water Volume, gal} \times 8.34\ \text{lbs/gal})\,(\text{Desired Concentration, \%})}{(100\% - \text{Desired Concentration, \%})}$$

$$\text{Water Volume, gal} = \frac{(\text{Chemical, lbs})\,(100\% - \text{Desired Concentration, \%})}{(\text{Desired Concentration, \%})\,(8.34\ \text{lbs/gal})}$$

Preliminary Treatment

$$\text{Total Alkalinity}<50\text{ mg/L as CaCO}_3:\ \text{Copper Sulfate, lbs} = (0.9\text{ lbs/acre - ft})(\text{Volume, acre - ft})$$

$$\text{Total Alkalinity}>50\text{ mg/L as CaCO}_3:\ \text{Copper Sulfate, lbs} = (\text{Surface Area, acre})(5.4\text{ lbs/acre})$$

$$\text{Copper Sulfate, lbs (as Copper)} = \frac{(\text{Dosage, mg/L})\ (\text{Volume, MG})\ (8.34\text{ lbs/gal})}{(\text{Copper, \%, expressed as a decimal})}$$

$$\text{Citric Acid, lbs} = \frac{(\text{Copper Sulfate, lbs})}{2}$$

$$\text{Area, acres} = \frac{(\text{Length, ft})(\text{Width, ft})}{43{,}560\ \text{ft}^2/\text{acre}}$$

$$\text{Volume, acre - ft} = (\text{Area, acres})\ (\text{Depth, ft})$$

$$\text{Pond Volume, acre - ft} = \frac{(\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})}{43{,}560\ \text{ft}^2/\text{acre}}$$

$$\text{Pond Volume, gal} = (\text{Volume, acre - ft})(43{,}560\text{ft}^2/\text{acre})(7.48\text{gal}/\text{ft}^3)$$

$$\text{Pond Volume, gal} = (\text{Area, acres})(\text{Depth, ft})(43560\ \text{ft}^2/\text{acre})(7.48\text{ gal}/\text{ft}^3)$$

Coagulation/Flocculation

Design Criteria

$$\text{Detention Time, sec} = \frac{(\text{Volume, gal})\ (1{,}440\text{ min/day})\ (60\text{ sec/min})}{\text{Flow, gal/day}}$$

$$\text{Detention Time, min} = \frac{(\text{Volume, gal})\ (1{,}440\text{ min/day})}{\text{Flow, gal/day}}$$

Lime Dosage

$$\text{Lime Dosage, mg/L} = (\text{Alum Dosage, mg/L})\ (0.37)$$

$$\text{Lime Feed Rate, grams/min} = \frac{(\text{Lime Dosage, mg/L})\ (\text{Flow, gal/day})\ (3.785\text{ L/gal})}{(1{,}440\text{ min/day})\ (1{,}000\text{ mg/gram})}$$

$$\text{Lime Dosage, lbs/day} = \frac{(\text{Alum Feed Rate, lbs/day})\ (0.37)}{\text{Commercial Purity, \%, expressed as a decimal}}$$

Mixing Energy

Mechanical Mixers $G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$

Where: P = (hp)(0.90)

μ = density of water, (lbs)(sec)/ft^2

V = volume of flash mix, ft^3

Hydraulic Jump $G = \sqrt{\frac{(62.4)(H)}{(\mu)(T)}}$

Where: H = head loss or drop, ft

μ = density of water, (lb)(sec)/ft^2

T = time, sec

Variable Speed $G_2 = \frac{(G_1)}{\left[\frac{N_1}{N_2}\right]^{3/2}}$

Where: G_2 = velocity gradient at N_2 rpm, sec^{-1}

G_1 = max velocity gradient unit can achieve, sec^{-1}

N_1 = maximum rpm

N_2 = new rpm

Jar Test RPM Correction $T_1 = \frac{(G_2)(T_2)}{G_1}$

Where: T_1 = Time to equate velocity gradient correction, sec

G_2 = calculated velocity gradient, sec^{-1}

T_2 =detention time for unit process, sec

G_1 = maximum G for jar test machine, sec^{-1}

$$\text{Settling Velocity, cm/min} = \frac{(\text{SOR, gpd/ ft}^2)(3785\ \text{cm}^3/\text{gal})}{(1440\ \text{min/day})(929\ \text{cm}^2/\text{ft}^2)}$$

Jar Testing

$$\text{Liquid Solution, gram} = \frac{\text{Liquid Solution, grams required}}{\text{Concentration, \%, expressed as a decimal}}$$

$$\text{Concentration, mg/mL} = \frac{(\text{Concentration, lb/gal})(453{,}600\ \text{mg/lb})}{3{,}785\ \text{mL/gal}}$$

$$\text{Dose, }\mu\text{L} = \frac{(\text{Dose, mg/L})(\text{Jar Test Beaker Volume, L})}{(\text{Specific Gravity})(\text{Concentration, \%, expressed as a decimal})}$$

$$\text{Dosage, mg/L} = \frac{\text{Chemical Feed Rate, lb/day}}{(\text{Flow, MGD})(8.34\ \text{lbs/gal})}$$

Sedimentation

$$\text{Detention Time, hr} = \frac{(\text{Volume, gal})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

$$\text{Surface Overflow Rate (SOR), gal/day/ft}^2 = \frac{\text{Flow, gal/day}}{\text{Surface Area, ft}^2}$$

$$\text{Weir Overflow Rate (WOR), gal/day/lineal ft} = \frac{\text{Flow, gal/day}}{\text{Weir Length, ft}}$$

$$\text{Length of CIrcular Weir, ft} = (3.14)(\text{Weir Diameter, ft})$$

$$\text{Length of Rectangular Weir, ft} = (2)(\text{Weir Length, ft}) + (2)(\text{Weir Width, ft})$$

Filtration

Hook Gauge

$$\text{Volume, gal} = (\text{Filter Bay Length, ft})(\text{Filter Bay Width, ft})(\text{Water Drop, ft})(7.48\text{ gal/ ft}^3)$$

$$\text{Average Time, sec} = \frac{\text{Test}_1\text{, sec} + \text{Test}_2\text{, sec} \ldots + \text{Test}_n\text{, sec}}{\text{Number of Tests (n)}}$$

$$\text{Average Time, min} = \frac{\text{Average Time, sec}}{60\text{ sec/min}}$$

$$\text{Sand Area, ft}^2 = (\text{Sand Bed Length, ft})(\text{Sand Bed Width, ft})$$

$$\text{Filtration Rate, gal/min} = \frac{\text{Volume, gal}}{\text{Average Time, min}}$$

$$\text{Filtration Rate, gal/min/ ft}^2 = \frac{\text{Filtration Rate, gal/min}}{\text{Sand Area, ft}^2}$$

Filter Production Rate

$$\text{Filter Production Rate, gal/min} = (\text{Filtration Rate, gal/min/ ft}^2)(\text{Filter Area, ft}^2)$$

$$\text{Filter Production Rate, gal/day} = (\text{Filtration Production Rate, gal/min})(1{,}440\text{ min/day})$$

Filter Backwash Rate

$$\text{Backwash Water Volume, gal} = (\text{Backwash Rate, gal/min/ ft}^2)(\text{Backwash Time, min})(\text{Filter Area, ft}^2)$$

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

Dry Feeders

Feeder Calibration

$$\text{Average Sample Mass, grams} = \frac{\text{Sample}_1\text{, grams} + \text{Sample}_2\text{, grams} + \text{Sample}_n\text{, grams}}{\text{n (number of samples)}}$$

$$\text{Average Feed Rate, grams/min} = \frac{\text{Total Sample Mass, grams}}{\text{Sample Collection Time, min}}$$

$$\text{Average Feed Rate, lbs/day} = \frac{\text{(Average Feed Rate, grams/min) (1,440 min/day)}}{\text{453.6 grams/lb}}$$

$$\text{Feeder Setting, grams/min} = \frac{\text{(Dose, mg/L) (Flow, gal/day) (3.785 Liters/gal)}}{\text{(1,440 min/day) (1,000 mg/gram)}}$$

Liquid Feeders

Feeder Calibration

$$\text{Average Sample Volume, mL} = \frac{\text{Sample}_1\text{, mL} + \text{Sample}_2\text{, mL} + \text{Sample}_n\text{, mL}}{\text{n (number of samples)}}$$

$$\text{Average Feed Rate, mL/min} = \frac{\text{Total Sample Volume, mL}}{\text{Sample Collection Time, min}}$$

$$\text{Feed Rate, gal/day} = \frac{\text{(Average Feed Rate, mL/min) (1,440 min/day)}}{\text{3,785 mL/gal}}$$

$$\text{Feeder Setting, mL/min} = \frac{\text{(Dose, mg/L) (Flow, gal/day) (3.785 Liters/gal)}}{\text{(Concentration, mg/mL) (1,440 min/day)}}$$

$$\text{Feeder Setting, gal/day} = \frac{\text{(Dose, mg/L) (Flow, MGD) (8.34 lbs/gal)}}{\text{Concentration, lbs/gal}}$$

$$\text{Feeder Setting, gal/day} = \frac{\text{(Dose, mg/L) (Flow, MGD)}}{\text{(Concentration, \%, expressed as a decimal) (Specific Gravity)}}$$

Liquid Chemical Characteristics

$$\text{Density, lbs/gal} = (\text{Specific Gravity})(8.34\text{ lbs/gal})$$

$$\text{Specific Gravity} = \frac{\text{Density of Solution, lbs/gal}}{8.34\text{ lbs/gal}}$$

$$\text{Concentration, lbs/gal} = (\text{Density, lbs/gal})(\text{Concentration, \%, expressed as a decimal})$$

$$\text{Concentration, mg/mL} = \frac{(\text{Concentration, lbs/gal})(453{,}600\text{ mg/lb})}{3{,}785\text{ mL/gal}}$$

$$\text{Concentration, \%} = \frac{\text{Concentration, lbs/gal}}{\text{Density, lbs/gal}} \text{ X } 100\%$$

Detention Time

$$\text{Detention Time, sec} = \frac{(\text{Volume, gal})\ (24\text{ hrs/day})\ (60\text{ min/hr})\ (60\text{ sec/min})}{\text{Flow, gal/day}}$$

$$\text{Detention Time, min} = \frac{(\text{Volume, gal})\ (24\text{ hrs/day})\ (60\text{ min/hr})}{\text{Flow, gal/day}}$$

$$\text{Detention Time, hr} = \frac{(\text{Volume, gal})\ (24\text{ hr/day})}{\text{Flow, gal/day}}$$

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

Chlorination

$$\text{Chlorine Demand, mg/L} = \text{Chlorine Dose, mg/L} - \text{Chlorine Residual, mg/L}$$

$$\text{Total Chlorine Residual, mg/L} = \text{Combined Residual, mg/L} + \text{Free Residual, mg/L}$$

$$\text{Free Chlorine Residual, mg/L} = \text{Total Residual, mg/L} - \text{Combined Residual, mg/L}$$

$$\text{Combined Chlorine Residual, mg/L} = \text{Total Residual, mg/L} - \text{Free Residual, mg/L}$$

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

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

General Bleach Formulas

$$\text{Chlorine Dose, mg/L} = \frac{\text{(Bleach Fed, gal/day) (Available Chlorine, \%, expressed as a decimal)}}{\text{Flow, MGD}}$$

$$\text{Hypochlorite Feed Rate, gal/day} = \frac{\text{(Chlorine Dose, mg/L) (Flow, MGD)}}{\text{Available Chlorine, \%, expressed as a decimal}}$$

Bleach Dilutions

$$\text{Bleach Volume, gal} = \frac{\begin{bmatrix}\text{Desired Available Chlorine Concentration} \\ \text{\%, expressed as s decimal}\end{bmatrix}\begin{bmatrix}\text{Desired} \\ \text{Volume, gal}\end{bmatrix}}{\text{Bleach Available Chlorine, \%, expressed as a decimal}}$$

$$\text{Available Chlorine, \%} = \frac{\text{(Bleach, gal) (Available Chlorine, \%, expressed as a decimal)}}{\text{Desired Volume, gal}} \text{ X } 100\%$$

HTH

$$\begin{matrix}\text{HTH, lbs} \\ \text{(solution mix)}\end{matrix} = \frac{\text{(Desired Available Chlorine, \%, expressed as decimal) (Desired Volume, gal) (8.34 lb/gal)}}{\text{HTH Available Chlorine, \% expressed as a decimal}}$$

$$\text{Chlorine Dosage, mg/L} = \frac{\text{(HTH Feed Rate, lb/day)}\begin{pmatrix}\text{HTH Available Chlorine, \%} \\ \text{expressed as a decimal}\end{pmatrix}}{\text{(Flow, MGD)(8.34 lbs/gal)}}$$

$$\text{Available Chlorine, \%} = \frac{\text{(HTH, lb) (Available Chlorine, \%, expressed as decimal)}}{\text{(Hypochlorite Solution, gal) (8.34 lb/gal)}} \text{ X } 100\%$$

Substitution of HTH or Chlorine for Bleach, etc

$$\text{Chlorine, lb} = \text{(Available Chlorine, \%, expressed as decimal) (Bleach Volume, gal) (8.34 lbs/gal)}$$

$$\text{Chlorine, lb} = \text{(HTH, lb) (Available Chlorine, \%, expressed as decimal)}$$

$$\text{HTH, lb} = \frac{\text{Chlorine, lb}}{\text{Available Chlorine, \%, expressed as decimal}}$$

$$\text{HTH, lb} = \frac{\text{(Available Chlorine, \%, expressed as decimal) (Bleach, gal) (8.34 lb/gal)}}{\text{HTH, Available Chlorine, \%, expressed as a decimal}}$$

$$\text{Bleach, gal} = \frac{\text{Chlorine, lb}}{\text{(Bleach Available Chlorine, \%, expressed as decimal) (8.34 lb/gal)}}$$

$$\text{Bleach, gal} = \frac{\text{(HTH Available Chlorine, \%, expressed as decimal) (HTH, lb)}}{\text{(Bleach Available Chlorine, \%, expressed as decimal) (8.34 lb/gal)}}$$

Hardness, Carbonate and Noncarbonate

Laboratory Results TH = Total Hardness TA = Total Alkalinity	Noncarbonate Hardness (Lime & Soda Ash used)	Carbonate Hardness (Lime only used)	Lime Dosage Formula To be Used
(1) TH less than TA	0	TH	I
(2) TH = TA	0	TH	I
(3) TH greater than TA	TH – TA	TA	II

( ) means “concentration of”

I $\quad \text{Lime Dosage, mg/L} = (\text{C0}_2) + (\text{Total Hardness}) + (\text{Mg}) + (\text{Excess})$

II $\quad \text{Lime Dosage, mg/L} = (\text{C0}_2) + (\text{HCO}_3) + (\text{Mg}) + (\text{Excess})$

$$\text{Soda Ash Dosage, mg/L} = (\text{Total Hardness}) - (\text{HCO}_3) + (\text{Excess})$$

$$\text{Total Hardness} = (\text{Calcium Hardness}) + (\text{Magnesium Hardness})$$

$$\text{Chemical Required, lbs/day} = \frac{(\text{Dose, mg/L})\,(\text{Flow, MGD})\,(8.34\text{ lbs/gal})}{(\%\text{ Commercial Purity, expressed as a decimal})}$$

Softening

Alkalinity Constituents
Alkalinity, mg/L as $CaCO_3$

Titration Results	Bicarbonate	Carbonate	Hydroxide
P = 0	T	0	0
P is less than ½ T	T – (2)(P)	(2)(P)	0
P = ½ T	0	(2)(P)	0
P is greater than ½ T	0	(2)(T) – (2)(P)	(2)(P) – T
P = T	0	0	T

Where P = phenolphthalein alkalinity, mg/L as $CaCO_3$

T = total alkalinity, mg/L as $CaCO_3$

Alkalinity

$$\text{Phenolphthalein Alkalinity, mg/L as } CaCO_3 = \frac{(A)(N)(50{,}000)}{\text{Sample Volume, mL}}$$

$$\text{Total Alkalinity, mg/L as } CaCO_3 = \frac{(B)(N)(50{,}000)}{\text{Sample Volume, mL}}$$

Where:

A = mL of titrant used to reach pH 8.3

B = total mL of titrant used

N = acid normality

Fluoridation

Chemical	Formula	Purity		Available Fluoride Ion (AFI)	
		Percent	Decimal	Percent	Decimal
Sodium Fluoride	NaF	98%	0.980	45.2%	0.452
Sodium Fluorosilicate	Na_2SiF_6	98.5%	0.985	60.7%	0.607
Fluorosilicic Acid	H_2SiF_6	23%	0.230	79.2%	0.792

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

$$\text{Feed Rate, lbs/min} = \frac{(\text{Dose, mg/L})\ (\text{Flow, gal/min})\ (8.34\ \text{lbs/gal})}{(1{,}000{,}000)\ (\text{AFI, expressed as decimal})\ (\text{Purity, expressed as a decimal})}$$

$$\text{Feed Rate, grams/min} = \frac{(\text{Feed Rate, lbs/day})\ (453.6\ \text{grams/lb})}{(1440\ \text{min/day})}$$

$$\text{Saturator Feed Rate, gal/min} = \frac{(\text{Dose, mg/L})\ (\text{Flow, gal/min})}{(18{,}000\ \text{mg/L})}$$

$$\text{Calculated Dosage, mg/L} = \frac{(\text{Fluoride, lbs})\ (\text{AFI, expressed as decimal})\ (\text{Purity, expressed as decimal})}{(\text{Flow, MGD})\ (8.34\ \text{lbs/gal})}$$

$$\underset{(\text{Saturator})}{\text{Calculated Dosage, mg/L}} = \frac{(\text{Solution Fed, gal/day})\ (18{,}000\ \text{mg/L})}{(\text{Flow, gal/dayl})}$$

Corrosion Control

$$\text{Langelier Index (LI)} = \text{pH} - \text{pH}_S$$

$$\text{pH of Saturation } (\text{pH}_S) = A + B - \log \text{Calcium Hardness} - \log \text{Total Alkalinity}$$

$$\text{Aggressive Index (AI)} = \text{pH} + \log \text{Calcium Hardness} + \log \text{Total Alkalinity}$$

Values of "A" for various Temperatures, °C	
Temperature, °C	A
0	2.34
5	2.27
10	2.2
15	2.12
20	2.04
25	1.98
30	1.91
40	1.76
50	1.62
60	1.47

Values for "B" for various levels of	
TDS, mg/L	B
0	9.63
50	9.72
100	9.75
200	9.8
400	9.86
800	9.94
1,600	10.04

Values of log of Ca or Alkalinity as $CaCO_3$ in mg/L	
mg/L	$\log_{10}$
10	1.00
20	1.30
30	1.48
40	1.60
50	1.70
60	1.78
70	1.84
80	1.90
90	1.95
100	2.00
200	2.30
300	2.48
400	2.60
500	2.70
600	2.78
700	2.84
800	2.90
900	2.95
1,000	3.00

Corrosivity Characteristics as Addressed by Indices		
Corrosive Characteristics	Langelier Index (LI)	Aggressive Index (AI)
Highly Aggressive	< - 2.0	< 10.0
Moderately Aggressive	- 2.0 to < 0.0	10.0 to < 12.0
Non-aggressive	> 0.0	> 12.0