SECTION 3 - SUMMARY OF KEY DISTRIBUTION OPERATOR MATH FORMULAS

General:

1.	Lbs/Day	=	(Vol, MGD) x (Dosage, mg/l) x 8.34 lbs/gal)
2.	Dosage, mg/l	=	$\frac{\text{(Feed, lbs/day)}}{\text{(Vol, MGD) x 8.34 lbs/gal)}}$
3.	Rectangular Basin Volume, cu. ft.	=	(Length, ft) x (Width, ft) x (Height, ft)
	i) Vol, Gals	=	Multiply the above by the factor 7.48 gals/cu.ft.
4.	Right Cylinder Volume, cu. ft.	=	(0.785) x (D^2, ft.) x (Height or Depth,ft)
	i) Vol, Gals	=	Multiply the above by the factor 7.48 gals/cu.ft.

5.	Conical Base Volume, cu. ft.	=	$\frac{\text{(0.785) x (}D^2\text{,ft)}}{(3)}$ x (Height or Depth,ft)
	i) Vol, Gals	=	Multiply the above by the factor 7.48 gals/cu.ft.
6.	Trapezoid, Volume cu. ft.	=	$\frac{(B_1 + B_2)}{2}$ x Height, ft x Length, ft.
	i) Vol, Gals	=	Multiply the above by the factor 7.48 gals/cu.ft.
7.	Removal, Percent	=	$\frac{\text{(In - Out)}}{\text{In}}$ x 100
8.	Decimal Fraction	=	$\frac{\text{(Percent)}}{100}$

GPCD **means** **<u>Gallons Per Capita Per Day</u>. A Capita is one (1) person.**

9. Gals/Day of Water Consumption, (Demand/Day) = (Population) x (Gals/Capita/Day)

<u>Consumption Averages, per capita:</u>

1. **Winter - 170 GPCD**
2. **Spring - 225 GPCD**
3. **Summer - 325 GPCD**

10. Gals/Capita/Day, Average Water Usage $= \dfrac{\text{(Vol, Gals/day)}}{\text{(Population, Served per day)}}$

11. Supply, Days (Full to Tank Dry) $= \dfrac{\text{(Vol, Gals/day)}}{\text{(Population Served) x (GPCD)}}$

12. **GPD** $= \dfrac{\text{(Meter Read 2, Gals - Meter Read 1, Gals)}}{\text{(Number of Days)}}$

13. **GPH** $= \dfrac{\text{(Volume, gallons)}}{\text{(Pumping Time, min. x 60 Min/Hr)}}$

14. **Time, Hrs.** $= \dfrac{\text{(Volume, gallons)}}{\text{(Pumping Rate, GPM x 60 Min/Hr)}}$

15. **Supply, Hrs. (Full to Tank Dry)** $= \dfrac{\text{(Storage Volume, Gals)}}{\text{(Flow In, GPM - Flow Out, GPM) x 60 min/hr.}}$

16. **GPD Combined Consumption** = **(Pump In, GPD) + (Clearwell Storage Volume, GPD Used)**

17. **Percent (%) of Increase** $= \dfrac{\text{(Larger Amount)}}{\text{(Smaller Amount)}} - 1.0 \times 100$

Chlorine Feed, Dosage/Demand/Residual:

Gas Chlorine Feed, Lbs/day

1. Lbs/Day = (Vol, MGD) x (Conc., mg/l) x (8.34 lbs/gal)

Dosage, mg/l $= \dfrac{(\text{Lbs/day})}{(\text{MGD}) \times (8.34 \text{ lbs/gal})}$

65% HTH Feed, Lbs/day - Calcium Hypochlorite

2. HTH, lbs/Day $= \dfrac{(\text{Vol, MGD}) \times (\text{Conc., mg/l}) \times (8.34 \text{ lbs/gal})}{(0.65)}$

Dosage, mg/l $= \dfrac{(\text{Lbs/day} \times 0.65)}{(\text{MGD}) \times (8.34 \text{ lbs/gal})}$

Lbs, 65% HTH $= \dfrac{(\text{Gals of Water} \times 8.34 \text{ lbs/gal}) \times \% \text{ Solution}}{(0.65)}$

5-1/4% - 12.5% Liquid Chlorine - Sodium Hypochlorite

3. Lbs/Gal $= \dfrac{(\text{Solution Percentage})}{100} \times 8.34 \text{ lbs/gal} \times \text{S.G.}$

GPD $= \dfrac{(\text{Vol, MGD}) \times (\text{Conc., mg/l}) \times (8.34 \text{ lbs/gal})}{(\text{Lbs/gal})}$

Dosage/Demand/Residual

4. Dosage, mg/l = (Demand, mg/l) + (Residual, mg/l)

5. Demand, mg/l = (Dosage, mg/l) - (Residual, mg/l)

6. Residual, mg/l = (Dosage, mg/l) - (Demand, mg/l)

C●t Calculations

1. **C●t = (Chlorine Residual, mg/L) x (Time, minutes**

2. **Time, minutes** $= \dfrac{(\ \text{C●t}\ )}{(\ \text{Chlorine Residual, mg/L}\ )}$

3. **Chlorine Residual, mg/L** $= \dfrac{(\ \text{C●t}\ )}{(\ \text{Time, minutes}\ )}$

4. Inactivation Ratio $= \dfrac{(\ \text{Actual System C●t}\ )}{(\ \text{Table "E" C●t}\ )}$

5. **C●t Calculated** = **T_{10} Value, minutes x Chlorine Residual, mg/L**

6. Log Removal $= \dfrac{(\ 1.0\ -\ \%\ \text{Removal}\ )}{100}$ x **Log key x (-)**

SECTION 3 - SUMMARY OF KEY DISTRIBUTION OPERATOR MATH FORMULAS - Continued

Fluoridation:

1. Feed, Lbs/day = $(\text{MGD}) \times \dfrac{(\text{mg/L})}{\left(\dfrac{\%\ \text{Purity}}{100} \times \dfrac{\%\ \text{Fluoride}}{100}\right)} \times 8.34\ \text{lbs/gallon} \times \text{S.G.}$

2. Adjusted Feed, Lbs/day = $(\text{MGD}) \times \dfrac{(\text{Desired, mg/L} - \text{Existing mg/L})}{\left(\dfrac{\%\ \text{Purity}}{100} \times \dfrac{\%\ \text{Fluoride}}{100}\right)} \times 8.34\ \text{lbs/gallon} \times \text{S.G.}$

3. Dosage, mg/L = $\dfrac{\left(\text{Feed, Lbs/day} \times \dfrac{\%\ \text{Purity}}{100} \times \dfrac{\%\ \text{Fluoride}}{100}\right)}{(\text{MGD}) \times 8.34\ \text{lbs/gallon} \times \text{S.G.}}$

SECTION 3 - SUMMARY OF KEY WATER DISTRIBUTION OPERATOR MATH FORMULAS - Continued

1. Hydraulic (Water Column Height) Pressure :

i) **PSI** = $\dfrac{(\text{Head, ft.})}{2.31 \text{ ft./PSI}}$

ii) **PSI** = **Head, ft. x 0. 433 PSI/ft.**

Or,

iii) **Head, ft.** = **PSI x 2.31 ft./PSI**

iv) **Head, ft** = $\dfrac{\text{PSI}}{0.433 \text{ PSI/ft.}}$

Pounds of Force On The Face of a Valve

2) Force, lbs = (Area, Sq. Inches) x PSI,

Or,

3) **Force, lbs = $(0.785)(\text{D, ft.})^2$ x 144 sq.in/sq.ft. x PSI.**

Bottom Force and Buoyancy

Tank Bottom Forces:

Rectangular Basins

4) **Force, lbs = L, ft x W,ft, x H, ft, x 62.4 lbs/cubic foot**

Right Cylinders

5) **Force, lbs = $(0.785)(\text{D, ft.})^2$ x Height, ft. x 62.4 lbs/cu.ft.**

Pounds Per Square Foot on a Tank Bottom:

Rectangular Basins

6) **Force, lbs** = $\dfrac{\text{L, ft x W,ft, x H, ft, x 62.4 lbs/cubic foot}}{(\text{Bottom Area, sq. ft.})}$

Right Cylinders

7) **Force, lbs** = $\dfrac{(0.785)(\text{D, ft.})^2 \text{ x Height, ft. x 62.4 lbs/cu.ft.}}{(\text{Bottom Area, sq. ft.})}$

Change of Direction

8. Force, lbs (Any Bend) = **2 x [$\text{Area}_{\text{sq.in.}}$ x $\text{Pressure}_{\text{, Psi}}$] x (1/2 Sin Θ)**

SECTION 3 - SUMMARY OF KEY DISTRIBUTION OPERATOR MATH FORMULAS - Continued

SCADA

1. **Feet of Water In A Tank :**

$$\text{Ft. Water} = \frac{(\text{Process Variable, mA} - 4.0\text{ mA})}{(20\text{ mA} - 4.0\text{ mA})} \times \text{Tank Height, ft.}$$

Live Signal

2. **mA Reading :**

$$\text{mA Reading} = \frac{(\text{Water Depth, Ft.})}{(\text{Tank Height, ft.})} \times (20\text{ mA})$$

Pumps and Pumping:

1. Pumping Rate:

Volume, Gals = GPM x Time, minutes

$$\text{Rate, GPM} = \frac{(\text{Tank Volume, Gals})}{(\text{Time, minutes})}$$

$$\text{Time, minutes} = \frac{(\text{Tank Volume, Gals})}{(\text{Fill Rate, GPM})}$$

2. Pump Size:

$$\text{Water Horsepower} = \frac{(\text{GPM}) \times (\text{Total Head, ft})}{(3{,}960)}$$

$$\text{Brake Horsepower} = \frac{(\text{GPM}) \times (\text{Total Head, ft})}{(3{,}960) \times (\%\ \text{Efficiency})}$$

% Overall Effic. (Pump/Motor) = (Motor, % Effic. x Pump % Effic.)

3. Pumping Cost:

$$\text{Cost, \$} = (\text{BHp}) \times (0.746\ \text{Kw/Hp}) \times (\text{Operating Hrs.}) \times \frac{\text{¢/Kw-Hr.}}{100}$$

4. Wells:

Drawdown, ft. = Pumping Level, ft. - Static Level, ft.

$$\text{Specific Capacity, GPM/ft.} = \frac{\text{Well Yield, GPM}}{\text{Drawdown, ft.}}$$

SECTION 3 - SUMMARY OF KEY DISTRIBUTIONOPERATOR MATH FORMULAS - Continued

Strength of Solutions:

1. **Chemical Feed Pumps:**
GPD (Gals) = **(Required Feed, Lbs/Day) / (Dry lbs/Gal)** = **(MGD) x mg/L x 8.34 lbs/gal / (Dry Lbs/gal)**
2. **Chemical Feed Rate:**
GPD = (**Feed, ml/min.** x 1,440 min/day) / (1,000 ml/L x 3.785 L/Gal)
GPM = (Feed, ml/min) / (3,785 ml/Gal)
ml/min = (**GPD** x 1,000 ml/L x 3.785 L/Gal) / (1,440 min/day)
ml/min = (GPM x 3,785 ml/Gal)

3. Lbs/gallon = (% Solution) x 8.34 lbs/gallon x (Specific Gravity) / (100)

4. Lbs Chemical = Specific Gravity x 8.34 lbs/gallons x Gallons of Solution

5. Specific Gravity = (8.34 lbs/gallon **+** Chemical Wt., Lbs/gallon) / (8.34 lbs/gallon)

6. Specific Gravity, Lbs/gallon = (S.G. x 8.34 lbs/gal) **-** (8.34 lbs/gal)

7. % Percent of Chemical in Solution = (Dry Chemical, Lbs) / (Dry Wt. Chemical, Lbs) **+** (Water, Lbs) x 100

8. Two-Normal Equations:

   a) $\mathbf{C_1V_1 = C_2V_2}$ **b)** $\mathbf{\frac{Q_1}{V_1} = \frac{Q_2}{V_2}}$

9. Three Normal equations:

   a) $\mathbf{(C_1 V_1) + (C_2 V_2) = (C_3 V_3)}$

Sedimentation Tanks and Clarifiers:

Hydraulic Cross-check Formulas:

1. **Surface Loading Rate, GPD/sq ft. = $\frac{\text{(Total Flow, GPD)}}{\text{(Surface Area, sq.ft.)}}$**
   Design Data: 800 - 1,200 GPD/Sq.ft.

2. **Detention Time, Hrs. = $\frac{\text{(Volume, gals) x (24 Hrs./day)}}{\text{(Total 24 Hr. Flow, Gals/day)}}$**
   Design Data: 1 - 4 Hours; Average 2.5 Hrs.

3. **Flow, GPD = $\frac{\text{(Volume, gals) x (24 Hrs./day)}}{\text{(Detention Time, Hrs.)}}$**

4. **Weir Overflow Rate, GPD/L.F. = $\frac{\text{(Flow, GPD)}}{\text{(Weir length, ft.)}}$**
   Design Data: 10,000 - 40,000 GPD/LF; Average 20,000 GPD/L.F.

5. Circumference, ft = 3.141 (Pi) x Diameter, ft.

6. Solids Loading Rate, lbs/day/sq. ft. = $\frac{\text{(Solids into Clarifier, lbs/day)}}{\text{(Surface Area, sq. ft.)}}$

7. Sludge Solids, lbs = (Flow, Gals) x (8.34 lbs/gal) x (Sludge, %)

8. Raw Sludge Pumping, gpm = $\frac{\text{(Settleable Solids, ml/L) x (Plant Flow, GPM)}}{\text{(1,000 mls/L)}}$

9. Sludge Volume Index, mg/l (SVI) = $\frac{\text{(Settled Sludge Volume, ml/l) x (1,000 mg/G)}}{\text{(Suspended Matter, mg/l)}}$

10. mg/l = $\frac{\text{(ml x 1,000,000)}}{\text{(ml sample)}}$

SECTION 3 - SUMMARY OF KEY DISTRIBUTION OPERATOR MATH FORMULAS - Continued

Velocity:

1. **Q, cfs** = **(Area, sq. ft.) x (Velocity, fps)**

$$\frac{(\text{GPM})}{(448.8\ \text{GPM/cfs})} = (0.785) \times (D, ft)^2 \times \frac{(\text{Distance, ft.})}{(\text{Time, seconds})}$$

2. **Velocity. fps** = $\frac{(\text{Q, cfs})}{(\text{Area, sq. ft.})}$

3. **Area, sq. ft.** = $\frac{(\text{Q, cfs})}{(\text{Velocity, fps})}$

4. Flow Conversions:

Flow, GPM = (Q, cfs) x (448.8 GPM/cfs)

5. Q, Cfs = $\frac{(\text{Flow, GPM})}{(448.8\ \text{GPM/cfs})}$

6. Pipe Diameter, Inches = $\sqrt{\frac{(\text{Area, sq.ft.})}{(0.785)}} \times 12$ inches/ft

7. Actual Leakage, GPD/Mile-inch = $\frac{\textbf{Leak Rate, GPD}}{\textbf{(Length, Mile) x (Diameter, inch)}}$

Note: **Minimum Flushing Velocity: 2.5 FPS**
Maximum Pipe Velocity: 5.0 FPS

Key Conversions: **1.55 cfs/mgd** **448.8 GPM/cfs**

Headloss Due to Friction:

1. **Darcy-Weisbach:**

   Headloss, ft $= (f) \dfrac{L_{,ft} \times V^2}{D_{,ft} \times 2g}$ (Use Moody Diagram for "f")

2. **Hazen - Williams**

   Q, gpm $= 0.28 \times C \times D^{2.63} \times S^{0.54}$

   "C" Factor $= \dfrac{\text{Flow, gpm}}{193.75\,(D,ft)^{2.63} \times (\text{Slope})^{0.54}}$

   HL/1,000 ft. $= \left(\dfrac{147.85 \times GPM}{C \times d^{2.63}}\right)^{1.852}$

   $V_{,fps} = 1.32 \times C \times R^{0.63} \left(\dfrac{H}{L}\right)^{0.54}$

3. **Manning**

   C, cfs $= \dfrac{1.49}{n} AR^{2/3} S^{1/2}$

   Slope $= \left[\dfrac{CFS \times n}{1.49 \times AR^{2/3}}\right]^2$

SECTION 3 - SUMMARY OF KEY DISTRIBUTION OPERATOR MATH FORMULAS - Continued

Ion Exchange:

1. **Calcium Hardness as mg/l $CaCO_3$ = (2.5) x (Calcium, mg/l)**

2. **Magnesium Hardness as mg/l $CaCO_3$ = (4.1) x (Magnesium, mg/l)**

3. **Total Hardness = Calcium + Magnesium Hardness as $CaCO_3$.**

4. **Convert Hardness from mg/l to grains/gallon:**

   Grains/gallon = (Total Hardness, mg/l) / (17.1 mg/l/Grain

$$\text{Grains/gallon} = \frac{(\text{Total Hardness, mg/l})}{(17.1\ \text{mg/l/Grain}}$$

5. Total Exchange Capacity, Kilograins = (Resin Cap., kilograins/cu.ft.) x (Vol, cu.ft.)

6. Total Grains Capacity = Kilograins x 1,000

7. Gals of Soft Water per Service Run = **(Total Exchange Capacity x Kilograins x 1,000)** / (Total Hardness as $CaCO_3$, **Grains/gallon**)

$$\text{Gals of Soft Water per Service Run} = \frac{(\text{Total Exchange Capacity x Kilograins x 1,000})}{(\text{Total Hardness as } CaCO_3\text{, Grains/gallon})}$$

8. **By-Pass Water, GPD**

$$\text{By-Pass Water, GPD} = \frac{(\text{Flow, GPD}) \times (\text{Effluent Hardness, Gr/Gal})}{(\text{Influent Hardness, Gr/Gal})}$$

9. **By-Pass Water, %**

$$\text{By-Pass Water, \%} = \frac{(\text{Discharge Hardness, mg/l})}{(\text{Initial Hardness, mg/l})} \times 100$$

10. **Salt, lbs**

$$\text{Salt, lbs} = \frac{(\text{Capacity, Grains}) \times (\text{Salt, lbs})}{(\text{1,000 Grains})}$$

Ion Exchange Formulas

(Continued)

11. **Brine, Gals** $= \dfrac{\text{(Salt Needed, lbs)}}{\text{(Salt, lbs/gallon)}}$

12. **Hardness Removed, Grains** $= \dfrac{\text{(Influent Hardness, mg/l - Effluent Hardness, mg/l)}}{\text{(17.1 mg/L/Grain)}}$

13. **% of Soft Water By-pass** $= \dfrac{\text{(Blended Discharge Hardness, mg/L)}}{\text{(Initial Hardness, mg/L)}} \times 100$

14. **GPM By-Pass** $= \dfrac{\text{(\% By-Pass)}}{100} \times \text{(Total Flow, GPM)}$

15. **Total Flow Thru Softener, GPM** $= \text{(Total Flow, GPM)} - \text{(By-Pass Flow, GPM)}$

Lime - Soda Ash Softening

16. Lbs Hardness Removed $= \text{(MGD)} \times \text{(Dosage, mg/L} \times \dfrac{\text{(Soda Ash - Mol Wt.)}}{\text{(Calcium Carbonate Mol Wt.)}} \times 8.34 \text{ lbs/gal}$

Laboratory:

1. $$\text{TSS (mg/l)} = \frac{\text{Paper Wt. and Dried Solids(g) - Paper Wt.(g)}}{\text{(Milliliters [ml] of Sample)}} \times 1{,}000{,}000$$

2. $$\text{Total Solids, mg/l} = \frac{\text{(Residue, mg) x 1,000}}{\text{(ml sample)}}$$

3. $$\text{Total Alkalinity, Mg/l} = \frac{\text{(mls of titrant x Normality x 50,000)}}{\text{(mls of Sample)}}$$

4. Langelier Index = (pH - pH, Saturated)

5. Concentrations:

   (Conc. 1) x (Volume 1) = (Conc. 2) x (Volume 2)

6. $$\text{mg/l} = \frac{\text{(ml x 1,000,000)}}{\text{(ml sample)}}$$

   mg/l = ml x 1,000 ml/L

7. $$\text{mg/l Total Solids} = \frac{\text{(Residue, mg) x 1,000}}{\text{(ml sample)}}$$

8. Temperature:

   $$F^\circ = (C^\circ \times 1.8) + 32^\circ$$

   $$C^\circ = \frac{(F^\circ - 32^\circ)}{(1.8)}$$

ABBREVIATIONS

Ac-ft	Acre feet
AFC	Actual fluoride content
C°	Celsius
Cf	Cubic feet (ft^3)
CCF	Hundred Cubic Feet
CFS	Cubic Feet Per Second
F°	Fahrenheit
Gal	Gallon(s)
GPM	Gallons Per Minute
GPD	Gallons Per Day
GPH	Gallons Per Hour
GPCD	Gallons per capita per day
H	Height
Hp	Horsepower
BHp	Brake Horsepower
Whp	Water Horse power
KW-Hrs	Kilowatt hours
Lbs	Pounds
Lbs/Day	Pounds per day
L	Liter
M	Meter
M	Mile
mg/l	Milligram per Liter
MGD	Million Gals/Day
ml	Milliliter
m.s.l.	Measured to Sea Level
ppm	Parts per Million
Q	Flow, cu. ft/sec.
π	Pi (3.141)
Sq. ft.	Square feet (ft^2)
Sq. Yd	Square Yards (ft^3)
SWD	Side Wall Depth
μ g/L	Microgram/Liter
V	Velocity
V	Volume

END

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