Calculations Used in the Daily Operations of a Water Treatment Plant

BAXTER & WOODMAN
Consulting Engineers

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The calculations provided in this booklet are tools, much like the mechanical and test equipment utilized, that will enable the operator to manage and run a water system as efficiently and smoothly as possible.

Operating a water system can be challenging, yet very rewarding. These systems are designed taking into account various hydraulic and operating conditions, and with equipment that will allow for efficient operation. However, running the equipment alone is not enough to ensure a smooth operation. The operator must use the calculations provided to operate the system effectively. While the operator can choose which calculations to use, it is imperative that the facility is run following operational guidelines in the original design specifications or the manufacturers' O&M manuals.

We hope you find this guide helpful.
If you have any questions or need further assistance,
please call Baxter & Woodman at 815-459-1260.

Contents

Definitions & Abbreviations

- **Cubic feet (ft^3)** - A unit of volume equal to a cube with a dimension of 1 foot on each side.
- **Feet per second (ft/sec, or fps)** - A unit used to express the rate of movement.
- **Gallons per day (gpd)** - A unit used to describe the discharge or flow past a fixed point during a 24 hour period.
- **Gallons per minute (gpm)** - A unit used to describe the discharge or flow past a fixed point during a 1 minute period.
- **Grain (gr)** - A unit of weight.
- **Grain per gallon (gpg)** - A unit used in reporting water analysis concentrations.
- **Liter (L)** - A unit of volume.
- **Parts per million (ppm)** - A unit of proportion equal to 10^{-6}.
- **Pounds per day (lb/day)** - A unit used to describe the rate at which a chemical is added to water.
- **Square foot (ft^2)** - A unit of area equal to a square with a dimension of 1 foot on each side.

Conversions

- 1 psi (pound per square inch) = 2.31 feet of elevation
- Minutes in a day = 1,440
- 1 cubic foot of water = 7.48 gallons
- Weight of 1 cubic foot of water = 62.4 pounds
- Weight of 1 gallon of water = 8.34 pounds
- Liters of water in a gallon = 3.785
- 1 part per million (ppm) or 1 milligram per liter (mg/L) = 1,000 part per billion (ppb)
- 1 ppb = 0.001 ppm or 0.001 mg/L
- $\Pi = 3.14$
- 1 grain = 17.1 mg/L of hardness
- 10,000 mg/l = 1%

Calculations Used in the Daily Operation of a Potable Water System

Several basic equations are used in calculations to determine things such as Flow Rate, Tank or Pipe Volume, Chemical Dosing, etc. The formulas for area and volume appear below, along with examples.

AREA

Area	**Formula**	**Example**
Rectangle	(Length) x (Width)	(35'L) x (12'W) = 420 square feet
Circle	$(\pi) \times (\text{radius})^2$	(3.14) x (20') x (20') = 1,256 sq. ft.
Sphere (surface area)	$(4) \times (\pi) \times (\text{radius})^2$	$(4) \times (3.14) \times (90')^2$ = 101,736 sq. ft.

Volume

Volume	**Formula**	**Example**
Rectangle	(Length) x (Width) x (Height)	(80'L) x (25'W) x (10'H) = 20,000 cu. ft.
Cylinder or Pipe	$(\pi) \times (\text{radius})^2 \times (\text{Height})$	(3.14) x (20') x (20') x (50') = 62,800 cu. ft.
Sphere	$\frac{(4) \times (\pi) \times (\text{radius})^2}{3}$	$\frac{(4) \times (3.14) \times (20') \times (20') \times (20')}{3}$ = 33,493 cu. ft.

Chemical Dosage

Used to determine how many pounds of chemical to be fed.

Convert volume of water to Million Gallons by dividing volume of water by 1,000,000.

MG = million gallons of water
mg/l = chemical dosage in milligrams per liter
8.34 lbs. = weight of 1 gallon of water

(MG) x (8.34) x (mg/l) = pounds of chemical at 100% pure.

If the chemical is not 100% pure, divide the pounds of chemical by the percentage (in decimal form) of the chemical.

Solution Mixing

Used to dilute a strong solution.

Q_s = quantity of strong solution in gallons
C_s = concentration of strong solution in mg/l or percentage (%)
Q_w = quantity of weak solution in gallons
C_w = concentration of weak solution in mg/l or %

$Q_sC_s = Q_wC_w$

Water Height/Based on Pressure

Used to calculate level of water in a well or a water tank.

PSI x 2.31 = Feet of water

Static level = Measurement from the surface of the water level in a well when the well has been off for approximately 1 hour.

Pumping level = Measurement from the ground surface to the water level in a well when the well is on and has been pumping for approximately 1 hour.

Drawdown = The difference between the Static level and the Pumping level (static – pumping)

Well yield = The gallons per minute (GPM) that the well is producing.

Specific capacity = GPM divided by the feet of drawdown (GPM / ft. drawdown)

Pumping Calculations

A well pumping 400 gallons per minute can pump how many gallons per day?

(1,440 min./day) x (400 gpm) = 576,000 gallons per day (gpd)

How many million gallons per day would the above well pump?

$$\frac{576{,}000 \text{ gpd}}{1{,}000{,}000} = 0.576 \text{ mgd}$$

How long would it take the above well to fill a 150,000 gallon water tower?

$$\frac{150{,}000 \text{ gallons}}{400 \text{ gpm}} = 375 \text{ minutes} = \frac{375 \text{ min.}}{60 \text{ min./hr.}} = 6 \text{ hrs. } 15 \text{ min.}$$

Water Main Calculations

How many gallons of water will it take to fill 1,200 feet of 10-inch water main?

Volume = (π) x $(\text{radius})^2$ x (Length)

Note: Diameter = 10 inches, so the radius = 10" / 12" per foot = 0.8333 ft.

(3.14) x (0.8333 ft.) x (0.8333 ft.) x 1,200 ft. = 2,616 cu. ft.

2,616 cu. ft. x 7.48 gals. / cu. ft. = 19,568 gals.

How much more water can an 8-inch water main carry compared to a 6-inch water main?

Radius of 8" water main = 8" / 12" per ft. = 0.666 ft.

Radius of 6" water main = 6" / 12" per ft. = 0.5 ft.

1 ft. of 8" water main can hold (π) x $(\text{radius})^2$ x (Length)

(3.14) x (0.666 ft.) x (0.666 ft.) x 1 ft. = 1.39 cu. ft. (ft^3)

(1.39 ft^3) x 7.48 gals./ ft^3 = 10.4 gals.

1 ft. of 6" water main can hold (π) x $(\text{radius})^2$ x (Length)

(3.14) x (0.5 ft.) x (0.5 ft.) x 1 ft. = 0.785 cu. ft. (ft^3)

(0.785 ft^3) x 7.48 gals./ ft^3 = 5.9 gals.

The 8" water main can hold 4.5 gals./ft. more water than the 6" water main, or 1.76 times more water.

How much water must you flow from fire hydrants on an 8-inch water main to get the water within the pipe moving at a rate of 2 feet per second (fps)?

2 fps x 60 seconds/minute = 120 ft. per minute

Volume = (π) x $(\text{radius})^2$ x (Length)

(3.14) x (0.666 ft.) x (0.666 ft.) x (120 ft./min.) = 167.1 ft^3/min.

(167.1 ft^3/min.) x (7.48 gals./ft^3) = 1,250 gpm

Chemical Calculations

How much Hydrofluosilicic Acid (fluoride) must be fed to treat 1 million gallons and provide a 1 mg/L fluoride concentration?

The formula for hydrofluosilicic acid is $H_2 Si F_6$.

Known: The commercial acid is 23% by weight pure acid and the remainder is water.
Note: The strength of commercial acid sometimes varies. You need to verify the strength on the label or with your supplier.

First, find the percent of fluoride in the $H_2 Si F_6$, by adding the relative atomic weights of each element within the compound.

$$\begin{aligned} H &= 2 \times 1.008 = 2.016 \\ Si &= 1 \times 28.0 = 28.09 \\ F &= 6 \times 19.00 = \underline{114.00} \\ & \qquad\qquad\quad 144.106 \end{aligned}$$

Therefore, $H_2 Si F_6$ = 144.106

To find the percentage of fluoride in the hydrofluosilicic acid ($H_2 Si F_6$):

$$\frac{\text{Atomic weight of fluoride (F)}}{\text{Atomic weight of } H_2 Si F_6} = \frac{114.00}{144.106} \times 100 = 79.11\%$$

Since commercial acid is 23% $H_2 Si F_6$, and 79.11% of this is pure fluoride, the percent of fluoride in commercial acid is:

0.23 x 0.7911 x 100 = 18.20%

Chemical formula:

$$\text{Flow in Million Gallons (MG)} \times 8.34 \text{ lbs/gal.} \times \text{mg/L (chemical dosage)} = \frac{\text{lbs. of chemical}}{\text{Strength of chemical}}$$

$$1 \text{ MG} \times 8.34 \times 1 \text{ mg/L} = \frac{8.34 \text{ lbs.}}{.1820 \text{ (18.20\% written as a decimal)}} = 45.82 \text{ lbs of commercial acid required}$$

A 150,000 gallon elevated storage tank is taken out of service for inspection and interim painting. Prior to putting the tank back into service, it is to be disinfected with a 50 mg/l of chlorine solution using HTH (70% available chlorine). Determine how many pounds of HTH will be needed to disinfect the tank.

$$\text{Volume of water (MG)} \times 8.34 \text{ lbs./gal.} \times \text{mg/l (dosage)} = \frac{\text{pounds of HTH}}{0.70 \text{ (70\%)}}$$

$$\frac{150{,}000}{1{,}000{,}000} \times 8.34 \times 50 \text{ mg/l} = \frac{\text{\# of HTH}}{.70}$$

$$0.15 \text{ MG} \times 8.34 \times 50 = \frac{62.55}{.70}$$

89.36 lbs. of HTH will be needed to disinfect the tank.

Ion Exchange Softening Calculation

An ion exchange softening plant has three softeners which are each 6 ft. in diameter. The media is 4 ft. deep in each unit. The media is rated to remove 20 kilograins per cubic foot. How many gallons of water having 380 mg/L hardness can be treated by the units before they need to be regenerated? If the flow rate to the softeners is 450 GPM, how long can they run before regeneration is needed?

Find the bed capacity:

Bed Volume = (3 units) x (π) x (radius^2) x (depth of media)

Bed Volume = (3) x (3.14) x (3 ft.) x (3 ft.) x (4 ft.)

Bed Volume = 339.12 cubic feet (round to 339 ft^3)

$$(339\ \cancel{ft^3}) \times \frac{20{,}000\ \text{grains}}{\cancel{\text{cubic foot}}} = 6{,}780{,}000 \text{ grains of bed capacity}$$

Then, convert 380 mg/L to grains:

$$(380\ \cancel{mg/L}) \times \frac{1\ \text{grain}}{17.1\ \cancel{mg/L}} = 22.2 \text{ grains}$$

Find the gallons of water treated:

$$\frac{(1\ \text{gallon})}{(22.2\ \cancel{\text{grains}})} \times (6{,}780{,}000\ \cancel{\text{grains}}) = 305{,}405 \text{ gallons}$$

Find the duration of the filter run:

$$(305{,}405\ \cancel{\text{gallons}}) \times \frac{(1\ \text{minute})}{(450\ \cancel{\text{gal}}.)} = 679 \text{ minutes (or 11 hours and 32 minutes)}$$

Detention Time Calculation

Known: A detention basin is 20 ft. x 20 ft. x 16 ft. deep.
If a 60 minute detention time is required, how many MGD can be treated in the basin?

$$\text{Basin Volume} = (20\ \cancel{ft}.) \times (20\ \cancel{ft}.) \times (16\ \cancel{ft}.) \times \frac{(7.48\ \text{gal.})}{(\cancel{\text{cubic ft}}.)}$$

Basin Volume = 47,872 gallons

$$\text{Flow Rate} = \frac{47{,}872\ \text{gallons}}{60\ \text{min.}} = 798 \text{ gallons per minute}$$

Convert 798 gpm to MGD:

$$\frac{(798\ \text{gal.})}{\cancel{\text{min}}.} \times \frac{(1440\ \cancel{\text{min}}.)}{\text{day}} = 1{,}149{,}120 \text{ gallons per day (or 1.15 MGD)}$$

Filtration Calculation

A plant has four filters that are each 12 ft. square. If the plant treated 1,640,000 gallons in 24 hours of continuous operation, calculate the average filtration rate.

$$\text{Filtration Rate} = \frac{\text{total gallons treated per unit of time}}{\text{total filter surface area}}$$

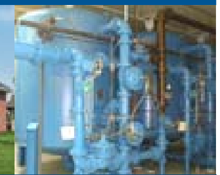
$$\text{Filtration Rate} = \frac{\text{1,640,000 GPD/1440 minutes per day}}{\text{(4) x (12 ft.) x (12 ft.)}}$$

$$\text{Filtration Rate} = \frac{\text{1138.8 GPM (round to 1139)}}{\text{576 sq. ft.}}$$

Filtration Rate = 1.98 GPM/sq. ft.

Water/Wastewater Operations





Baxter & Woodman provides a full range of services to meet your daily and long-term operational needs, complemented by a staff that provides customized Municipal Engineering Services. Licensed and certified operators are available to assist with your water and wastewater operations needs.

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Lab assistance
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NPDES permit applications
Land application permits
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Maintenance programs
Operator training
Odor control issues

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Troubleshooting
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Cross connection programs

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Baxter & Woodman, Inc. is an employee-owned engineering consulting firm which provides planning, design, construction and technology services for water, wastewater, stormwater and transportation facilities for municipalities, counties and state agencies throughout the Midwest.

Founded in 1946, Baxter & Woodman is one of the largest regionally focused engineering firms in the Midwest. Clients are served from nine regional offices. Baxter & Woodman's staff of 200 engineers, surveyors, technicians and support personnel has completed projects for more than 500 municipalities and county governments.

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