1 Fractions

- A fraction is defined as part of whole. If in a class there are 20 male students and 30 male students, the fraction of male students is $\frac{20}{50} or \frac{2}{5}$.
- It is composed of three items: two numbers and a line.
- The number on the top is called the numerator, the number on the bottom is called the denominator, and the line in between them means to divide.

$$\text{Divide} \longrightarrow \frac{3}{4} \quad \begin{array}{l}\text{Numerator}\\ \text{Denominator}\end{array}$$

- A proper fraction is a fraction that has no whole number part and its numerator is smaller than its denominator. An improper fraction is a fraction that has a larger numerator than denominator and it represents a number greater than one.
  Proper Fraction Examples: $\frac{1}{2}, \frac{5}{8}, \frac{11}{12}$
  Improper Fraction Examples: $\frac{12}{2}, \frac{5}{2}$
- Any whole number can be expressed as a fraction by placing a "1" in the denominator. For example: 2 is the same as $\frac{2}{1}$ and 45 is the same as $\frac{45}{1}$
- Only fractions with the same denominator can be added/subtracted, and only the numerators are added/subtracted. For example:

$$\frac{1}{8} + \frac{3}{8} = \frac{4}{8} \text{ and, } \frac{7}{8} - \frac{3}{8} = \frac{4}{8}$$

- A fraction combined with a whole number is called a mixed number. For example:

$$4\frac{1}{8},\ 16\frac{2}{3},\ 8\frac{3}{4},\ 45\frac{1}{2} \text{ and, } 12\frac{17}{32}$$

  These numbers are read, four and one eighth, sixteen and two thirds, eight and three fourths, forty-five and one half, and twelve and seventeen thirty seconds.
  Mized numbers
- A fraction can be changed by multiplying the numerator and denominator by the same number. This does not change the value of the fraction, only how it looks. For instance:

$$\frac{1}{2} \text{ is the same as } \frac{1}{2} \times \frac{2}{2} \text{ which is } \frac{2}{4}$$

- Steps to convert $\frac{17}{4}$ to a mixed number:
  1. How many times can 4 fit into 17? 4 because 4×4=16. Thus, 4 becomes the whole number part
  2. How much is left over in the numerator? 1 because $17 - 16 = 1$. Thus, 1 becomes the numerator of the fractional part
  3. $\frac{17}{4} = 4\frac{1}{4}$

- To turn a mixed number into an improper fraction, multiply the whole number part by the denominator and add the numerator. This becomes the new numerator over the original denominator.
  Example: Converting 1.5 feet to fraction
  $1.5ft = 1\frac{1}{2}$
  $1\frac{1}{2} = \frac{1*2+1}{2} = \frac{2+1}{2} = \frac{3}{2}$

- A mixed value - say a circumference is given in feet and fraction of feet (say 7 3/4), needs to be converted to a fraction for calculation purposes.

2 Ratio

- Ratio is used for comparing the size of two or more quantities.
- Say if there are 10 red cubes and 5 pink marbles in a bag, the ratio $\frac{5}{10}$ is the ratio of pink marbles and red cubes. It can also be represented by 5:10.
- 5 lbs of chemical in 10 gallons solution is a ratio. So is 30 miles per gallon.
- Unlike fractions, ratio does not compare things that have the same units.

3 Proportion

- Two quantities are said to be in proportion if one changes, the other changes in a specific way.
- Two quantities are said to be directly proportional, if the **increase** in one will **increase** the other value proportionally.
  - Thus, if two quantities x and y are directly proportional, its ratio $\frac{x}{y}$ will be a fixed value. Thus for x_1 and y_1 different values of x and y respectively will be related by the equation $\frac{x}{y} = \frac{x_1}{y_1}$.
  - This relationship is useful for calculating unknown values in water treatment calculations as in the following example:

    Knowing 200 lbs of bleach is needed to disinfect 5 MG of water at a treatment plant, calculate the lbs of bleach required to disinfect 3.2 MGD flow.

    The ratio $\frac{200 \;\; pounds \;\; bleach}{5MG}$ or 40 lbs bleach per MG is a constant. Using this known proportion the lbs of bleach is needed to disinfect 3.2 MG at this plant can be calculated as follows by setting up the equation as:

    $\frac{40 \;\; pounds \;\; bleach}{MG} = \frac{X}{3.2 \;\; MG}$ where X is the unknown lbs of bleach that is required to disinfect the 3.2 MG flow.

    X can be calculated by cross multiplying the above equation: $X = \frac{3.2 * 40}{1} = 128 \;\; lbs \;\; bleach$
- Two quantities are said to be inversely proportional if the **increase** in one will **decrease** the other value proportionally.
  - Thus, if two quantities x and y are inversely proportional, its product $x * y$ will be a fixed value and different values of x and y respectively will be related by the equation $x * y = x_1 * y_1$.
  - Examples of inversely proportional relationship include:
    * Labor hours required to perform a certain task or time required to pump down a wetwell depending on the size of the pump. An increase in assignment of labor hours will reduce the time required to perform the task
    * Using a larger pump will reduce the time to pump down the wetwell.
    * In the Pounds formula:

$$lbs \;\; \textbf{or} \;\; \frac{lbs}{day} = Concentration\left(\frac{mg}{l}\right) * 8.34 * volume(MG) \;\; \textbf{or} \;\; Flow(MGD)$$

for the same lbs or lbs/day, concentration varies inversely with volume or flow. Thus, for a certain pounds added, the concentration will go down if the flow increases and vice versa.

* In the flow equation, Q=V*A, for the same flow (Q), velocity (V) and surface area (A) are inversely related. If Q is remaining the same, an increase in surface area will reduce the velocity and vice versa.
  Additionally, for a flow through a pipe as the surface area of the pipe is proportional to the square of the diameter, the velocity in the pipe is inversely proportional to the square of the diameter.

  For a constant Q: $V * A = V_1 * A_1$ or $V * D^2 = V_1 * D_1^2$

- Application of inversely proportional relationship in water related calculation can be demonstration with the following example:
  If it takes 20 minutes to pump a wet well down with one pump pumping at 125 gpm, then how long will it take if a 200 gpm pump is used?
  As this is an inversely proportional relationship (a larger pump will reduce the time required):
  $(20\text{minutes} * 125\text{gpm}) = (X\text{minutes} * 200\text{gpm})$
  where X is the unknown time to pump down the wetwell with the 200 gpm pump.
  Solving for X: $X = \frac{20 * 125}{200} = 12.5$ minutes

4 Decimals & Powers of Ten

- A decimal is composed of two sets of numbers: the numbers to the left of the decimal are whole numbers, and numbers to the right of the decimal are parts of whole numbers, a fraction of a number.
- The term used to express the fraction component is dependent on the number of characters to the right of the decimal.
  - The first character after the decimal point is tenths: 0.1 - tenths
  - The second character is hundredths: 0.01 - hundredths
  - The third character is thousandths: 0.001 - thousandths
- The term used to express the fraction component is dependent on the number of characters to the right of the decimal.
  - The first character after the decimal point is tenths: 0.1 - tenths
  - The second character is hundredths: 0.01 - hundredths
  - The third character is thousandths: 0.001 - thousandths
- Powers of 10 notation enables us to work with these very large and small quantities efficiently.
- In water math, the most common application of this concept is related to parts per million (ppm) or parts per billion (ppb).
- 1 million - 1,000,000 can be represented as 10^6. Likewise, 1 billion - 1,000, 000,000 can be represented as 10^9
- The sequence of powers of ten can also be extended to negative powers.
- 1 part per million (1/1,000,000) can be written as 10^-6

Name	Power	Number	SI symbol	SI prefix
one	10^0	1		
ten	10^1	10	da (D)	deca
hundred	10^2	100	h (H)	hecto
thousand	10^3	1,000	k (K)	kilo
million	10^6	1,000,000	M	mega
billion	10^9	1,000,000,000	G	giga
tenth	10^{-1}	0.1	d	deci
hundredth	10^{-2}	0.01	c	centi
thousandth	10^{-3}	0.001	m	milli
millionth	10^{-6}	0.000 001	μ	micro
billionth	10^{-9}	0.000 000 001	n	nano

5 Rounding and Significant Digits

- Significant digits (also called Significant Figures) are digits which give us useful information about the accuracy of a measurement and are related to rounding.
- This concept is used to determine the direction to round a number (answer). The basic idea is that no answer can be more accurate than the least accurate piece of data used to calculate the answer.
- Significant digits is the count of the numerals in a measured quantity (counting from the left) whose values are considered as known exactly, plus one more whose value could be one more or one less.
- Rules for determining the number of significant digits:
  1. All nonzero digits are significant:
     1.234 g has 4 significant figures, and 1.2 g has 2 significant figures.
  2. Zeroes between nonzero digits are significant: 1002 kg has 4 significant figures, 3.07 mL has 3 significant figures.
  3. Zeroes to the left of the first nonzero digits are not significant; such zeroes merely indicate the position of the decimal point: 0.001 °C has only 1 significant figure, 0.012 g has 2 significant figures.
  4. Zeroes to the right of a decimal point in a number are significant: 0.023 mL has 2 significant figures, 0.200 g has 3 significant figures.
  5. When a number ends in zeroes that are not to the right of a decimal point, the zeroes are not necessarily significant: 190 miles may be 2 or 3 significant figures, 50,600 calories may be 3, 4, or 5 significant figures. The potential ambiguity in the last rule can be avoided by the use of standard exponential, or ”scientific,” notation. For example, depending on whether 3, 4, or 5 significant figures is correct, we could write 50,6000 calories as: $5.06 * 10^4$ calories (3 significant figures) $5.060 * 10^4$ calories (4 significant figures), or $5.0600 * 10^4)$ calories (5 significant figures).
- Examples of significant figures:
- Addition and Subtraction
  - When you are adding or subtracting a bunch of numbers and need to be concerned with significant figures, first add (or subtract) the numbers given in their entire format, and then round the final answer. When rounding the final answer after adding or subtracting, the answer must be written with the same significant figures as the least accurate decimal place given.
    Example: 13.214 + 234.6 + 7.0350 + 6.38
    * 13.214 + 234.6 + 7.0350 + 6.38 = 261.2290
    * 234.6 is only accurate to the tenths place making it the least accurate number. My answer must be rounded to the same place as the least accurate number:

1000 has one significant digit: only the 1 is interesting (only it tells us anything specific); we don't know anything for sure about the hundreds, tens, or units places; the zeroes may just be placeholders; they may have rounded something off to get this value.
1000.0 has five significant digits: the ".0" tells us something interesting about the presumed accuracy of the measurement being made; namely, that the measurement is accurate to the tenths place, but that there happen to be zero tenths.
0.00035 has two significant digits: only the 3 and 5 tell us something; the other zeroes are placeholders, only providing information about relative size.
0.000350 has three significant digits: the last zero tells us that the measurement was made accurate to that last digit, which just happened to have a value of zero.
1006 has four significant digits: the 1 and 6 are interesting, and we have to count the zeroes, because they're between the two interesting numbers.
560 has two significant digits: the last zero is just a placeholder.
560. : notice that "point" after the zero! This has three significant digits, because the decimal point tells us that the measurement was made to the nearest unit, so the zero is not just a placeholder.
560.0 has four significant digits: the zero in the tenths place means that the measurement was made accurate to the tenths place, and that there just happen to be zero tenths; the 5 and 6 give useful information, and the other zero is between significant digits, and must therefore also be counted.

    * 261.2290 rounds to 261.2 (one decimal place)

- Multiplication and Division

  - When multiplying or dividing multiple numbers you would do these calculations as normal. When the answer must be written in the appropriate significant figure your answer must round to the same number of significant figures as the least number of significant figures.
    Example 1: Simplify, and round, to the appropriate number of significant digits

    16.235 x 0.217 x 5

    1. First off, 5 has only one significant figure, thus the final answer needs to be rounded to one significant digit
    2. 16.235 x 0.217 x 5 = 17.614975
    3. To round 17.614975 to one digit. I'll start with the 1 in the tens place. Immediately to its right is a 7, which is greater than 5, so 1 is rounded up to 2, and then replacing the 7 with a zero, and dropping the decimal point and everything after it.
    4. 17.614975 rounds to 20

    Example 2: Simplify, and round, to the appropriate number of significant figures

    0.00435 x 4.6

    1. 4.6 has only 2 significant figures, so the final answer should be rounded to two significant figures.
    2. 0.00435 x 4.6 = 0.02001
    3. 0.02001 would round to 0.020, which has 2 significant figures (0.020). The answer cannot be 0.02, because that value would have only one significant figure.

- *A number is rounded off by dropping one or more numbers from the right and adding zeroes, if necessary, to maintain the decimal point.*

- *If the last figure dropped is 5 or more, increase the last retained figure by 1. If the last digit dropped is less than 5, do not increase the last retained figure.*

6 Averages

- Also known as *arithmetic mean*, this value is arrived at by adding the quantities in a series and dividing the total by the number in the series.

Example 1: Find the average of the following series of numbers: 12,8,6,21,4,5 , 9 , and 12.
Adding the numbers together we get 77.
There are 8 numbers in this set.
Divide 77 by 8.
$\frac{77}{8} = 9.6$ is the average of the set

Example 2: Find the average of the set of daily turbidity data - 0.3,0.4,0.3,0.1,and 0.8
The total is 1.9.
There are 5 numbers in the set.
Therefore:

$$\frac{1.9}{5} = 0.38, \text{ rounding off } = 0.4$$

7 Working with Percent

- Percent expresses portions of the whole.
- The whole is considered as 1 or 100% and a part of the whole can be expressed as a percent. **Example:** If a tank is $1/2$ full, we say that it contains 50% of the original solution.
- Percentage is written as a whole number with a % sign after it.
- In a calculation, percent is expressed as a decimal.
- The decimal form of a percent value is obtained by dividing the percent by 100.
  Example: 11% is expressed as the decimal 0.11, since 11% is equal to $11/100$. This decimal is obtained by dividing 11 by 100.
- To determine what percentage a part is of the whole, divide the part by the whole.
  Example: There are 80 water meters to read, Jim has finished 24 of them. What percentage of the meters have been read?

  $$24 \div 80 = 0.30$$

  The 0.30 is converted to percent by multiplying the answer by 100.

  $$0.30 \times 100 = 30\%$$

  Thus 30% of the 80 meters have been read.
- To find the percentage of a number, multiply the number by the decimal equivalent of the percentage given in the problem.
  Example:
  What is 28% of 286?

  1. Change the 28% to a decimal equivalent:

     $$28\% \div 100 = 0.28$$

  2. Multiply $286 \times 0.28 = 80$
     Thus 28% of 286 is 80.
- To increase a value by a percent, add the decimal equivalent of the percent percent to " 1 " and multiply it times the number.

  Example: A filter bed will expand 25% during backwash. If the filter bed is 36 inches deep, how deep will it be during backwash?

  1. Change the percent to a decimal.

     $$25\% \div 100 = 0.25$$

  2. Add the whole number 1 to this value.

     $$1 + 0.25 = 1.25$$

  3. Multiply times the value.

     $$36 \text{ in } \times 1.25 = 45 \text{ inches}$$

7.1 Percentage Concentrations

Above concepts are used for chemicals such as fluoride and hypochlorites - the strength of the product as used is commonly expressed as a percentage.
Example 1: A chlorine solution was made to have a 4% concentration. It is often desirable to determine this concentration in mg/L. This is relatively simple: the 4% is four percent of a million.
To find the concentration in mg/L when it is expressed in percent, do the following:

1. Change the percent to a decimal.

$$4\% \div 100 = 0.04$$

3. Multiply times a million.

$$0.04 \times 1,000,000 = 40,000\text{mg/L}$$

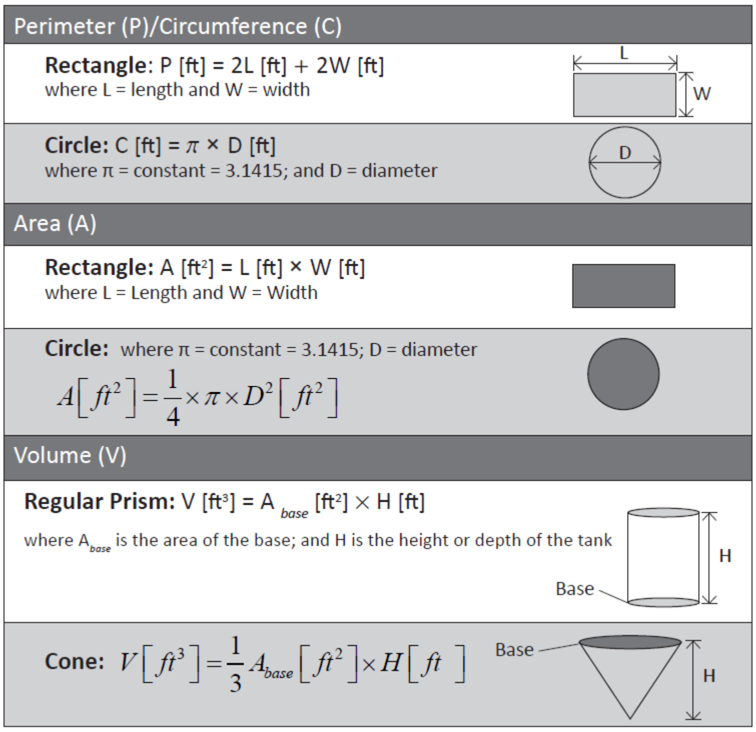
We get the million because a liter of water weighs $1,000,000$mg.1mg in 1 liter is 1 part in a million parts (ppm).$1\% = 10,000$mg/L.
Example 2: How much 65% calcium hypochlorite is required to obtain 7 pounds of pure chlorine?
65% implies that in every lb of calcium hypochlorite has 65% lbs of available chlorine.

$$\text{Therefore, } \frac{0.65 \text{ lbs available chlorine}}{\text{lb of calcium hypochlorite}} \text{ or conversely } \frac{\text{lb of calcium hypochlorite}}{0.65 \text{ lbs available chlorine}}$$

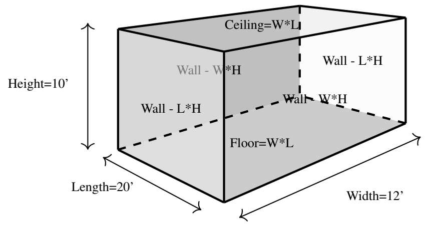
$$\implies \text{lbs calcium hypchlorite required} = \frac{\text{lb of calcium hypochlorite}}{0.65 \text{ lbs } \cancel{\text{available chlorine}}} * \frac{7 \text{ lb of } \cancel{\text{available chlorine}}}{}$$

$$= \boxed{\text{10.8 lbs of calcium hypochlorite with 65\%available chlorine is required}}$$

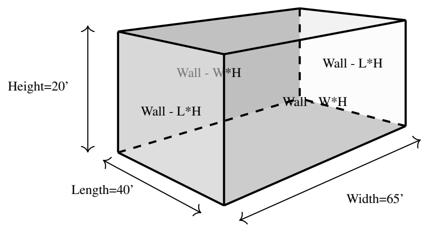
8 Area & Volume



Example 1: The floor of a rectangular building is 20 feet long by 12 feet wide and the inside walls are 10 feet high. Find the total surface area of the inside walls of this building
Solution:



2 Walls W*H + 2 Walls L*H= $2*12*10ft^2+2*20*10ft^2$
$= 240+400 = \boxed{640ft^2}$
2 Walls W*H + 2 Walls L*H + Floor + Ceiling= $2*12*10ft^2+2*20*10ft^2+2*12*20ft^2$
$= 240+400+480 = \boxed{1,120ft^2}$
Example 2: How many gallons of paint will be required to paint the inside walls of a 40 ft long x 65 ft wide x 20 ft high tank if the paint coverage is 150 sq. ft per gallon. Note: We are painting walls only. Disregard the floor and roof areas.
Solution:



2 Walls W*H + 2 Walls L*H = $2*65*20ft^2+2*40*20ft^2 = 2,600+1,600 = 4,200ft^2$

$$\implies @150\frac{ft^2}{gal}\ \ paint\ \ coverage\ \ \rightarrow\ \ \frac{4,200\cancel{ft^2}}{150\frac{\cancel{ft^2}}{gal}} = \boxed{28\ \ gallons}$$

Example 3: What is the circumference of a 100 ft diameter circular sedimentation tank?

Solution:

$$Circumference = \pi * D = 3.14*100ft = \boxed{314ft}$$

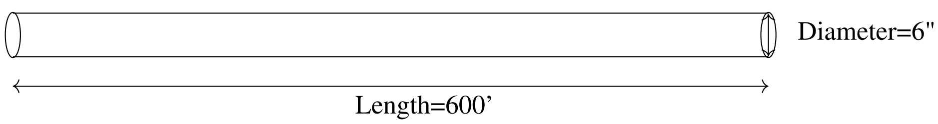
Example 4: If the surface area of a clarifier is 5,025ft^2, what is its diameter?

Solution:

$$Surface\ \ area = \frac{\pi}{4}*D^2 \quad \implies 5025(ft^2) = 0.785*D^2(ft^2)$$
$$\implies D^2 = \frac{5025}{0.785} \implies D = \sqrt{6401.3} = \boxed{80ft}$$

Example 5: How many gallons of water would 600 feet of 6-inch diameter pipe hold, approximately?

Solution:



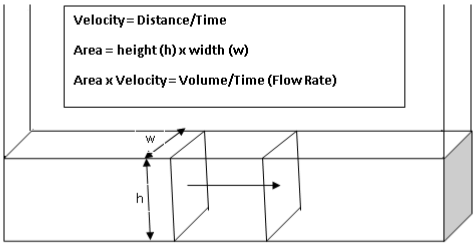
$$Volume = \frac{\pi}{4}D^2 * L = 0.785*\left(\frac{6}{12}\right)^2*600\cancel{ft^3}*7.48\frac{gallons}{\cancel{ft^3}} = \boxed{881\ \ gallons}$$

9 Flow and Velocity

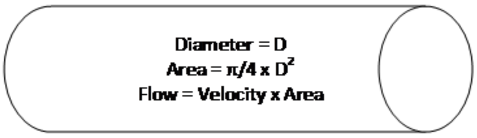
- Flow Rate - Q (volume/time) = velocity (distance or length traveled /time) * surface area
- Velocity is the speed at which the water is flowing. It is measured in units of length/time – ft./sec.
- Velocity of water flowing through can be calculated by dividing the flow rate by area of the flow stream.

$$Velocity\ \frac{length}{time} = \frac{flow\ rate(\dfrac{volume\ or\ cubic\ length}{time})}{surface\ area\ in\ the\ direction\ of\ flow - square\ length}$$

For a flow in a channel:



For a flow in a pipe:



Example 1: If a chemical is added in a pipe where water is flowing at a velocity of 3.1 feet per second, how many minutes would it take for the chemical to reach a point 7 miles away?
Note - we want the answer in minutes

$$\text{Min } = \frac{1}{3.1}\frac{sec}{ft} * \frac{5280ft}{mile} * 7miles * \frac{min}{60sec} = \boxed{199min}$$

Example 2: Find the flow in cfs in a 6 -inch line, if the velocity is 2 feet per second.

1. Determine the cross-sectional area of the line in square feet. Start by converting the diameter of the pipe to inches.

   The diameter is 6 inches: therefore, the radius is 3 inches. 3 inches is $3/12$ of a foot or 0.25 feet.

2. Now find the area in square feet.

$$A = \pi \times r^2$$
$$A = \pi \times \big(0.25\text{ft}^2$$
$$A = \pi \times 0.0625\text{ft}^2$$
$$A = 0.196\text{ft}^2$$

Or

$$A = 0.785 \times D^2$$
$$A = 0.785 \times 0.5^2$$
$$A = 0.785 \times .05 \times .05$$
$$A = 0.196\text{ft}^2$$

3. Now find the flow.

   $Q = V \times A$

   $Q = 2\text{ft}/\text{sec} \times 0.196\text{ft}^2$

   $Q = 0.3927\text{cfs or } 0.4\text{cfs}$

10 Concentration

- Concentration is typically expressed as mg/l which is the weight of the constituent (mg) in 1 liter of water.
- As 1 liter of water weighs 1 million mg, a concentration of 1 mg/l implies 1 mg of constituent per 1 million mg of water or one part per million (ppm). Thus, mg/l and ppm are synonymous.
- Sometimes the constituent concentration is expressed in terms of percentage.

  Example: 12.5% chlorine concentration solution.

  100% would mean 1,000,000 mg/l or 1,000,000 ppm

  $\Longrightarrow$ 1% would be $\frac{1,000,000}{100}$mg/l = 10,000 mg/l or 10,000 ppm

  $\Longrightarrow$ 12.5% chlorine concentration is 125,000 mg/l or 125,000 ppm.

  $1\%\ concentration = 10,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

  $0.1\%\ concentration = 1,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

  $0.01\%\ concentration = 100\ \ ppm\ \ or\ \ \frac{mg}{l}$

  $10\%\ concentration = 100,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

  $5\%\ concentration = 50,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

  $12.5\%\ concentration = 125,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

11 Density

- Density is defined as the weight of a substance per a unit of its volume. For example, pounds per cubic foot or pounds per gallon.
- Here are a few key facts about density:
  - Density is measured in units of lb/ft3, lb/gal, or mg/L. Density of water = 62.4 lb/ft3 = 8.34 lb/gal.

12 Specific Gravity

- Specific gravity is the ratio of the density of a substance (liquid or solid) to the density water.
- It is the ratio of the weight of the substance of a certain volume to the weight of water of the same volume.
- Any substance with a density greater than that of water will have a specific gravity greater than 1.0. Any substance with a density less than that of water will have a specific gravity less than 1.0.
- Specific gravity examples:
  - Specific gravity of water = 1.0
  - Specific gravity of concrete = 2.5 (depending on ingredients)

  - Specific gravity of alum (liquid @ 60°F) = 1.33
  - Specific gravity of hydrogen peroxide (35%) = 1.132

- Specific gravity is used in two ways:

  1. To calculate the total weight of a % solution (either as a single gallon or a drum volume).
     Total Weight = Drum Vol X SG X 8.34
  2. To calculate the "active ingredient" weight of a single gallon or a drum.
     Active Ingredient Weight within Drum = Drum Volume X SG X 8.34 X % solution as a decimal. (i.e., Total Weight X % solution as a decimal)
     NOTE: Both ways start with solving for the total weight (Drum Vol X SG X 8.34). When solving for "active ingredient" weight, you have to then multiply by % solution as a decimal.

Example: What is the weight of 5 gallons of a 40% ferric chloride solution given its specific gravity of 1.43?

$$(8.34 * 1.43)\ lbs/gal * 5\ \ gallons = \boxed{59.6\ \ lbs}$$

The weight of active ferric chloride in the drum will be 59.6*0.4=23.84 lbs (as ferric chloride is 40% strength)

13 Detention Time

- Detention Time - The actual or theoretical (calculated) time required for water to fill a tank at a given flow; pass through a tank at a given flow; or remain in a settling basin, flocculating basin, rapid-mix chamber, or storage tank.

  $$Tank/clarifier\ \ detention\ \ time\ \ (hr) = \frac{Tank/clarifier\ \ volume(cu.ft\ \ or\ \ gal)}{Influent\ \ flow\ \ (cu.ft\ \ or\ \ gal)/hr)}$$

  Rectangular tank/clarifier volume = width * length * depth of water
  Circular tank/clarifier volume = 0.785 * Diameter^2 * depth of water
  Typically volume is calculated in cu. ft and influent flow is given in gallons. Use 7.48 gal/ft^3 conversion factor to convert volume in cu. ft to gallons.

14 Unit Conversions

- A conversion is a number that is used to multiply or divide into a measure in order to change the units of the original measure.

Measure	**Units**
Length	inches, ft, miles
Area	ft^2, acres
Volume	ft^3, gallons, acres-ft.
Density	weight per volume, lbs/ft^3, lbs/gallon
Flow	ft^3/min, MGD, acres-ft/day

Table 1: Common units in water calculations

- In most instances, the conversion factor cannot be derived. It must be known. Therefore, tables such as the one below are used to find the common conversions.

Some Common Conversions	Weight
Linear Measurements	1ft^3 of water = 62.4lbs
1 inch = 2.54 cm 1foot = 30.5 cm 1 meter = 100 cm = 3.281feet = 39.4 inches 1 acre = 43,560ft^2 1yard = 3feet	1gal = 8.34lbs 1lb = 453.6grams 1 kg = 1000 g = 2.2lbs 1% = 10,000mg/L 1pound = 16ozdrywt 1ft^3 = 62.4lbs
Volume	Pressure
1gal = 3.78 liters 1ft = 7.48 gal 1 L = 1000 mL 1gal = 16cups	1ft of head = 0.433psi 1psi = 2.31ft of head
Flow	
1cfs = 448gpm 1gpm = 1440gpd	

- Common conversions in water related calculations include the following:
  - gpm to cfs
  - Million gallons to acre feet
  - Cubic feet to acre feet
  - Cubic feet of water to gallons
  - gpm to MGD
  - psi to feet of head

- Steps for unit conversion:
  1. Make sure the original unit is for the same measurement as the converted (desired) unit. So if the original unit is for area, say in ft^2 the converted unit should be another area unit such as in^2 or acre but it cannot be gallons as gallon is a unit of volume.
     Note: Calculating the weight of a certain volume of water involves the use of density which is the mass per volume - value in units including lbs/gallon or lbs/ft^3
  2. Write down the conversion formula as:
     $Quantity\ \ in\ \ converted\ \ unit = Quantity\ \ (\cancel{Original\ \ Unit}) * Conversion\ \ Factor\ \ \frac{Conversion\ \ unit}{\cancel{Original\ \ unit}}$

- Note: If you wish to convert cubic feet of water to pounds, you have to use its density which is the known mass per unit volume.
  $\frac{8.34\ \ lbs}{gallon}$ or $\frac{62.4\ \ lbs}{ft^3}$
  $mass\ \ of\ \ water = \cancel{Volume} * Density(\frac{mass}{\cancel{Volume}})$

Example Problems:

1. Convert 1000 ft^3 to cu. yards
   $1000\cancel{ft^3} * \frac{cu.yards}{27\cancel{ft^3}} = 37cu.yards$
2. Convert 10 gallons/min to ft^3/hr
   Note: This involves use of two conversion factors - one for converting gallons to cubic feet and another for converting minute to gallons.
   $\frac{10\cancel{gallons}}{\cancel{min}} * \frac{ft^3}{7.48\cancel{gallons}} * \frac{60\cancel{min}}{hr} = \frac{80.2ft^3}{hr}$

3. Convert 100,000 ft^3 to acre-ft.
$100,000\cancel{ft^3} * \frac{acre-ft}{43,560\cancel{ft^2-ft}} = 2.3acre-ft$

4. Convert 8 ft^3 of water to pounds.
Here the conversion is from a volume (ft^3) to a weight (lbs). It involves use of a standard correlation of the volume of water to its weight - its density.
$Weight\ \ of\ \ water\ \ in\ \ lbs = 8\cancel{ft^3} * 62.4(\frac{lbs}{\cancel{ft^3}}) = 499.2\ \ lbs$

14.1 Temperature Conversion

- Two scales are commonly used to measure temperature: degrees Fahrenheit (°F) and degrees Centigrade or Celsius(°C).
- Fahrenheit is the standard scale used in the U.S. and Celsius is the metric scale.
- In the Celsius scale, water freezes at 0°C and boils at 100°C. In the Fahrenheit scale, water freezes at32°F and boils at 212°F.
- The following factors can be used when converting from one temperature scale to another:

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

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

15 Contaminant Removal Efficiency

- Contaminant removal efficiency can be expressed as the percentage of the inlet concentration removed and can be established based upon the amount of a particular contaminant entering and leaving a treatment process.
- $Percent\ \ Removal\ \ (\%) = \frac{Concentration\ \ In - Concentration\ \ Out}{Concentration\ \ In} * 100$
- If 10 units of a contaminant are entering a process and 8 units of pollutant are leaving (process removes 2 units), then the process removal rate for that pollutant is (10-8)/10*100=20%. In this example the process is 20% efficient in removing that particular contaminant.
- Besides percent removal, removal efficiency can also be expressed in terms of Log removal.
- Background of log:
Log of a number x to the **base** B is the exponent to which B must be **raised** to produce x.

$$\log_B x = A \implies B^A = x$$
For Example: $\log_{10} 1000 = 3 \implies 10^3 = 1000$

Log Rules

1. $\log_b 1 = 0$
2. $\log_b ac = \log_b a + \log_b c$
3. $\log_b \frac{a}{c} = \log_a a - \log_b c$
4. $\log_b a^r = r \log_b a$
5. $\log_b \frac{1}{c} = -\log_b c$

- Log removal is: $\log_{10}(Concentration\ \ In) - \log_{10}(Concentration\ \ Out)$

- **CASE 1:** Say the initial (before treatment) and final (after treatment) cryptosporidium concentrations are 100 oocysts and 10 oocysts per L respectively.

  Thus log removal is $\log_{10} 100 - \log_{10} 10 = \log_{10} \frac{100}{10} = \log_{10} 10 = \boxed{1}\ \ as\ \ 10^1 = 10$

- The removal on a percentage basis: $\text{Percent\ \ removal} = \frac{\text{initial} - \text{final}}{\text{intial}} * 100 = \frac{100-10}{100} * 100 = 90\%$

- **CASE 2:** Say the initial (before treatment) and final (after treatment) cryptosporidium concentrations are 100 oocysts and 1 oocysts per L respectively.

  Thus log removal is $\log_{10} 100 - \log_{10} 1 = \log_{10} \frac{100}{1} = \log_{10} 100 = \boxed{2}\ \ as\ \ 10^2 = 100$

- The removal on a percentage basis: $\text{Percent\ \ removal} = \frac{\text{initial} - \text{final}}{\text{intial}} * 100 = \frac{100-1}{100} * 100 = 99\%$

- **CASE 3:** If the initial (before treatment) and final (after treatment) cryptosporidium concentrations are 1000 oocysts and 1 oocysts per L respectively. (unreal values....)

  Thus log removal is $\log_{10} 1000 - \log_{10} 10 = \log_{10} \frac{1000}{1} = \log_{10} 1000 = \boxed{3}\ \ as\ \ 10^3 = 1000$

  The removal on a percentage basis: $\text{Percent\ \ removal} = \frac{\text{initial} - \text{final}}{\text{intial}} * 100 = \frac{1000-1}{1000} * 100 = 99.9\%$

- Thus:
  1 log removal =90% removal efficiency
  2 log removal =99% removal efficiency
  3 log removal =99.9% removal efficiency
  4 log removal =99.99% removal efficnecy

16 Pounds Formula

- Pounds formula:

$$lbs\ \ \textbf{or}\ \ \frac{lbs}{day} = Concentration\left(\frac{mg}{l}\right) * 8.34 * volume(MG)\ \ \textbf{or}\ \ Flow(MGD)$$

- So if the concentration of a particular constituent (in mg/liter) and the volume or flow of wastewater is given, one can calculate the amount of that constituent or using this formula.
  Important notes:

  1. The unit of the constituent loading rate will be in lbs per the unit of time the flow is expressed in. So if the flow is in MG per day the calculated loading rate will be in lbs/day. Likewise if the flow value used is in MG per minute, the calculated loading rate will be in lbs/min.
  2. If volume is used, the calculated value will be the mass of the constituent in that volume. If flow is used, the calculated value will be the mass of the constituent in that flow.
  3. For the Pound Formula to work, the volume or flow needs to be expressed in MG. Volume or flows in other units - gallons, ft^3 etc. needs to be converted to MG.

- The formula assumes that all of the material found in water (TSS, BOD, MLSS, Chlorine, etc.) weighs the same as water, that is, 8.34 pounds per gallon.

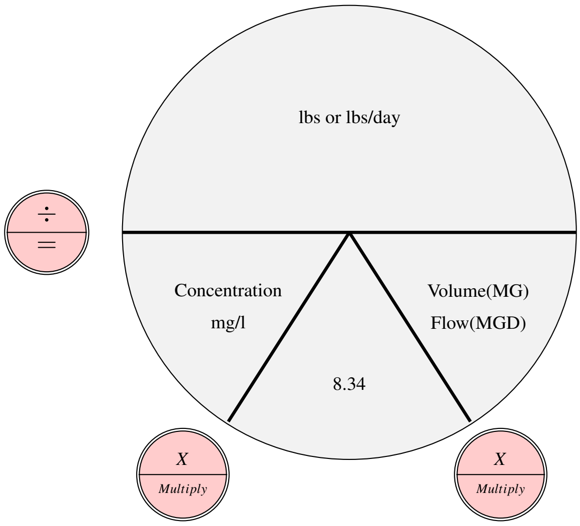


Figure 1: Davidson Pie

- In the Pounds Formula, there are three variables – lbs, concentration and volume, and one constant - 8.34. Knowing any of the two variables in the formula, one can calculate the third (unknown) variable by rearranging the equation.

- Davidson Pie provides a pictorial reference for calculating any unknown variable. If for example, if Concentration is unknown, it can be calculated as follows:

$$Concentration\left(\frac{mg}{l}\right) = \frac{lbs \ \textbf{ or } \ \frac{lbs}{day}}{8.34 * Volume(MG) \ \textbf{ or } \ Flow(MGD)}$$

- Likewise, if Volume (or Flow) is the unknown variable. it can be calculated as:

$$Volume(MG) \ \ or \ \ Flow(MGD) = \frac{lbs \ \textbf{ or } \ \frac{lbs}{day}}{Concentration\left(\frac{mg}{l}\right) * \ 8.34}$$

- Pounds formula is used for:
  - Calculating the quantity in pounds of a particular wastewater constituent entering or leaving a wastewater treatment process
  - Calculating the pounds of chemicals to be added

Example 1: If a 5 MGD flow is to be dosed with 25 mg/l of a certain chemical, calculate the lbs/day that chemical required.
Solution
Applying lbs formula:

$$\frac{lbs}{day} = 5MGD * 250\frac{mg}{l} * 8.34 = \boxed{1,042\frac{lbs}{day}}$$

Example 2: Calculate the lbs of chemical in 7,500 gallons of 4.5% active solution of that chemical.
Solution
Applying lbs formula:

$$lbschemical = \frac{7500}{1,000,000}MG * 4.5 * 10,000 * 8.34 = \boxed{2,815 \ \ lbs \ \ chemical}$$

Note:

1) 7500 gallons was converted to MG by dividing by 1,000,000

$$7500 \ \ gallons * \frac{1MG}{1,000,000 \ \ gallon}$$

2) 4.5% was converted to mg/l by multiplying by 10,000 as 1%=10,000mg/l

17 Chemicals Related Math Problems

17.1 Chemical Dosing

- Use lbs formula to calculate the lbs of chemicals required
- Using the calculated lbs chemical required value, calculate the amount of that chemical at the concentration available

So for example, if asked how much many gallons per day of bleach solution (SG 1.2)containing 12.5% available chlorine is required to disinfect a 10 MGD flow of water given the required chlorine dosage of 7 mg/l.

1. calculate the lbs of chlorine required using the lbs formula:

   $$=10MGD \ * \ 7\frac{mg}{l} \ * \ 8.34 \ = \ 583.8 \ \ lbs \ \ chlorine \ \ per \ \ day$$

2. calculate the gallons of bleach which will provide the 583.8 lbs chlorine

   Applying the lbs formula - note that 8.34 * SG will give the actual lbs/gal of bleach. If SG is not provided, use only 8.34 lbs per gallon:

   $$583.8\frac{lbs \ \ bleach}{day} \ = \ x\frac{gal}{day} \ * \ 8.34*1.2\frac{lbs \ \ bleach}{gal} \ * \ 0.0125\frac{lbs \ \ chlorine}{lb \ \ bleach}$$

   $$\implies x\frac{gal}{day} \ = \ \frac{583.8}{8.34*1.2*0.125} \ = \boxed{467\frac{gal}{day}}$$

The above problem can be solved directly using the formula below given in the SWRCB Water Treatment Exam Formula Sheet.

$$\text{GPD} = \frac{(\text{MGD})*(\text{ppm or mg/l})*8.34 \ \ \text{lbs/gal}}{\% \ \ \text{purity}*\text{Chemical} \ \ \ \text{Wt. (lbs/gal)}} \quad \text{GPD} = \frac{10*7*8.34}{0.125*(1.2*8.34)} = \boxed{467\frac{\text{gal}}{\text{day}}}$$

17.2 Blending and Dilution Calculations

- Blending and dilution calculations apply to the following scenarios:
  - Blending involves mixing two streams - each with a different concentration of contaminant/chemical, to obtain a certain volume or flow containing the target concentration of contaminant/chemical. For example: *Finding the correct blend of two source water streams - one with 15 mg/L of iron and other containing 4 mg/L of iron to get a 100 gpm product water containing 8 mg/l of iron.* **OR**
    Calculating the actual combined TDS concentration obtained by mixing two known flows with known TDS concentrations.
  - Dilution involves makedown of a higher concentration of a chemical to a lower concentration using water as a dilutant. For example: *How much initial volume of a 4% polymer solution is needed to make 3500 gallons of polymer at 0.25% concentration?*

- These type of problems are solved using C*V relationship where:
  - C is the concentration expressed in ppm or mg/l or as % purity.
  - V is either the volume or flow.
  - The product - C*V - $\frac{\text{mass}}{\text{volume/flow}} * \text{volume/flow} = \text{mass}$
- For blended streams, the sum of the mass from each of the two source streams will equal to the mass in the target stream:
- Thus, **for blending calculations**, if:
  C_1 and V_1 is the concentration and volume respectively of the one of the sources streams and

  C_2 and V_2 is the concentration and volume respectively of the second source stream, and

  C_3 and and V_3 is the concentration and volume respectively of the target stream

  The sum of the mass from each of the two source streams will equal to the mass in the target stream:

  $C_1 * V_1 + C_2 * V_2 = C_3 * V_3$.

  This equation can be manipulated algebraically to calculate anyone of the unknown values in the equation.

  Also, any of the three volume variables can be expressed as the sum or difference of the other two - , or $V_1 + V_2 = V_3$ or $V_1 = V_3 - V_2$ or $V_2 = V_T - V_1$
- **For dilution**, the mass of the target chemical will remain the same, as only water is added to the source (concentrated chemical).
- Thus, for dilution calculations, if:

  C_1 and V_1 is the concentration and volume respectively of the concentrated product used for the dilution, and

  C_2 and V_2 is the concentration and volume of the resultant product after dilution with water

  The mass of the target chemical in the volume of the concentrated product used for dilution will remain the same in the final diluted product:

  $C_1 * V_1 = C_2 * V_2$.

Example Problem #1: Two wells are used to satisfy demand during the summer months. One well produces water that contains 22 mg/L of Arsenic. The other well produces water that contains 3 mg/L of Arsenic. If the total demand for water is 400 gpm and the target Arsenic concentration in the finished water is 8 mg/L, what is the highest pumping rate possible for the first well?

Solution:
$C_1 * V_1 + C_2 * V_2 = C_3 * V_3$

Thus $22 * V_{22} + 3 * V_3 = 8 * V_8$

$V_{22} + V_3 = V_8 = 400$ gpm

As we want to solve for V_{22}, we can express V_3 as: $V_3 = 400 - V_{22}$

Thus, $22 * V_{22} + 3 * (400 - V_{22}) = 8 * 400 = 3{,}200$

$22V_{22} + 1200 - 3V_{22} = 3{,}200$

$V_{22}(22-3) = 2{,}000$

$V_{22} = \frac{2{,}000}{19} = \boxed{105.3 \ gpm}$

Also, $V_3 = 400 - 105.3 = 294.7$

NOTE: If one does not want to utilize algebraic manipulation, one may memorize the following formula:

$$V_{1/2} = \frac{|C_3 - C_{2/1}| * V_3}{C_1 - C_2}$$

Applying the formula above to Example Problem #2:

$$V_{22} = \frac{|8-3| * 400}{22-3} = \boxed{105.3 \;\; gpm}$$

$$V_3 = \frac{|8-22| * 400}{22-3} = \boxed{294.7 \;\; gpm}$$

Example Problem #2: How many gallons of a 4% polymer solution is required to make a 3,500 gallon batch of 0.25% polymer solution.
Solution:

Here, we are adding water - which has zero percent of polymer concentration to the 4% polymer to make a 0.25% polymer solution.

$C_1 * V_1 = C_2 * V_2$

$C_{4\%} * V_{4\%} = C_{0.25\%} * V_{0.25\%}$

$4 * V_{4\%} = 0.25 * 3{,}500$

$$\implies V_{4\%} = \frac{0.25 \;\; * \;\; 3500}{4} = \boxed{219 \;\; \text{gal}}$$

Take 219 gallons of the 4% polymer and dilute to 3,500 gallons to give a 0.25% polymer solution.

18 Pumping Calculations

- Pump is a machine used for moving water (and other fluids) through a piping system and raise the pressure of the water.
- Pumping is accomplished by transforming the input energy - typically from an electric motor or from other sources such as high-pressure air.
- The pump calculations in this section are for electrically driven rotodynamic pumps.
- To move water, a pump will need to overcome resistance due its density, gravitational force and friction.
- This resistance is dependent on:
  - Height the water needs to be raised. This height of the fluid in a container is referred to as head.
  - Quantity of water involved

18.1 Glossary of Pump Calculations Terms

Force: In the English system force and weight are often used in the same way. The weight of the cubic foot of water is 62.4 pounds. The force exerted on the bottom of the one foot cube is 62.4 pounds. If we have two cubes stacked on top of one another, the force on the bottom will be 124.8 pounds.
Pressure: Pressure is a force per unit of area, pounds per square inch or pounds per square foot are common expressions of pressure.
Head: Pressure is directly related to the height of a column of fluid. This height is called head or feet of head. Pressure and feet of head head are directly related - *for every one foot of head there is a pressure of* 0.433 *psi.*

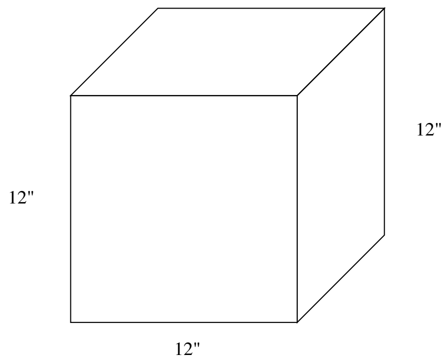
Thus, $\dfrac{0.433\ \ psi}{ft\ \ (water\ \ column)}$ or conversely $\dfrac{1\ \ ft\ \ (water\ \ column)}{2.31\ \ psi}$

Note: This pressure/head will include the height the water pumped and also the head associated with friction losses - energy loss because of the water moving through the pipe and fittings.

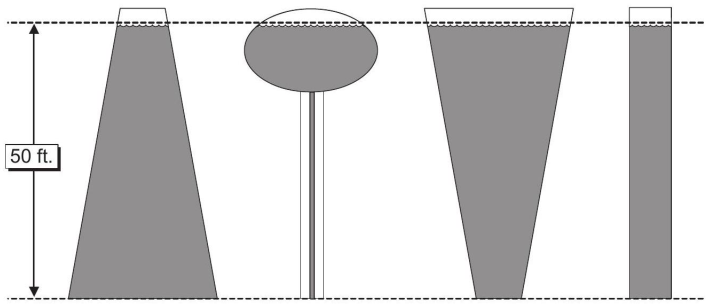
$$Pressure = \frac{Force}{Area}$$

Pressure exerted by a 1ft column of water $= \dfrac{62.4\ \ lb}{12in\ \ x\ \ 12in} = 0.43\ \ psi$

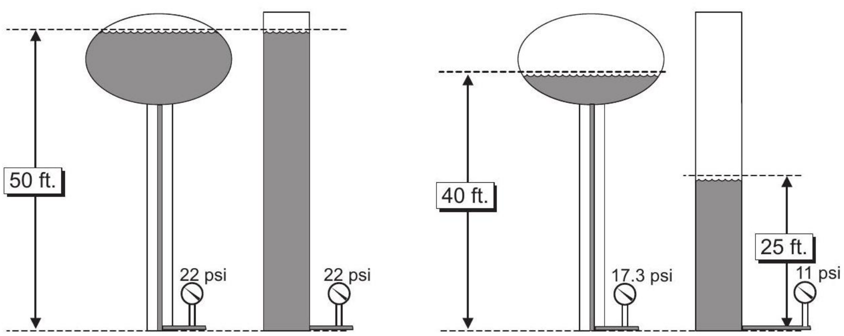
As $1 ft^3$ of water weighs 62.4 lbs



The pressure at the bottom of a container is affected only by the height of water in the container and not by the shape or the volume of the container. In the drawing below there are four containers all of different shapes and sizes. The pressure at the bottom of each is the same.



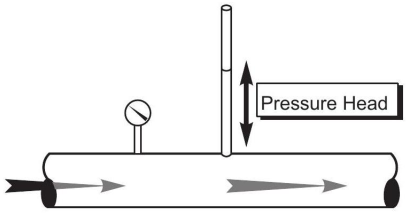
The pressure exerted at the bottom of a tank is relative only to the head on the tank and not the volume of water in the tank. For example, below are two tanks each containing 5000 gallons. The pressure at the bottom of each is 22 psi. If half of the water were drained from the tanks the pressure at the bottom of the elevated tank would be 17.3 psi while the pressure at the bottom of the standpipe would be 11 psi.



Velocity: Velocity is the speed that the water is moving along a pipe or through a basin. Velocity is usually expressed in feet per second, ft/sec.

Flow: Flow is commonly expressed in gallons per minute (gpm) and/or cubic feet per second (cfs). There is a relationship between gallons per minute and cubic feet per second. One cubic foot per second is equal to 448.8 gallons per minute.

1cfs = 448.8gpm
Flow Equation; The basic equation for determining flow is as follows:
$Q = V \times A$
Where:
$\mathrm{Q} = \mathrm{cfs}\left(\mathrm{ft}^3/\mathrm{sec}\right)$
$\mathrm{V} = \mathrm{ft}/\mathrm{sec}$
$\mathrm{A} = \mathrm{ft}^2$
Static Pressure: Static implies a non-moving condition. The pressure measured when there is no water moving in a line or the pump is not running is called static [32] pressure. This is the pressure represented by the gauges on the tanks in the discussion above.
Dynamic Pressure: When water is allowed to run through a pipe and the pressure (called pressure head) measured at various points along the way we find that the pressure decreases the further we are from the sources.

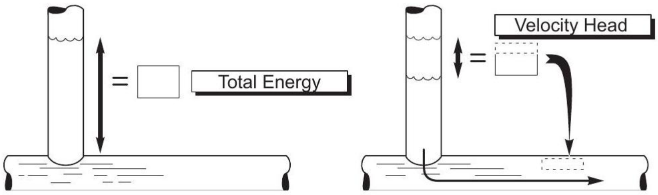


Headloss: The reason for this reduction in pressure is a phenomenon called headloss. Headloss is the loss of energy (pressure) due to friction. The energy is lost as heat.
If the headloss in a certain pipe is 25 feet, it means the amount of energy required to overcome the friction in the pipe is equivalent to the amount of energy that would be required to lift this amount of water straight in the air 25 feet.
In a pipe, the factors that contribute to headloss include the following:

- Roughness of pipe - If the roughness of a pipe were doubled the headloss would double.
- Length of pipe - If the length of the pipe were doubled the headloss would double.
- Diameter of pipe - If the diameter of a pipe were doubled the headloss would be cut in half
- Velocity of water - If the velocity of the water in a pipe were doubled the headloss would be increased by about four times. It should be apparent that velocity, more than any other single factor, affects headloss. To double the velocity we would have to double the flow in the line.
- Pumping System Components and Fittings - Each type of fitting has a specific headloss depending upon the velocity of water through the fitting. For instance the headloss though a check valve is two and one quarter times greater than through a ninety degree elbow and ten times greater than the headloss through an open gate valve.

Static Head: Static head is the distance between the suction and discharge water levels when the pump is shut off.
Suction Lift: Suction lift is the distance between the suction water level and the center of the pump impeller. This term is only used when the pump is in a suction lift condition. A pump is said to be in a suction lift condition any time the eye (center) of the impeller is above the water being pumped.
Velocity Head: The amount of energy required to bring a fluid from standstill to its velocity. For a given quantity of flow, the velocity head will vary indirectly with the pipe diameter.
Total Dynamic Head (TDH): The total energy needed to move water from the center line of a pump (eye of the first impeller of a lineshaft turbine) to some given elevation or to develop some given pressure. This includes the static head, velocity head and the headloss due to friction.
Horsepower: Horsepower is a measurement of the amount of energy required to do work. Motors are rated in horsepower. The horsepower of an electric motor is called brake horsepower. The horsepower requirements of a pump are dependent on the flow and the total dynamic head. 33,000 foot pounds per minute of work is 1 horsepower.

Suction Head: Suction head is the distance between the suction water level and the center of the pump impeller when the pump is in a suction head condition. A pump is said to be in a suction head condition any time the eye (center) of the impeller is below the water level being pumped.
Velocity Head: Velocity head is the amount of energy required by the pump and motor to overcome inertia and bring the water up to speed. Velocity head is often shown mathematically as $V^2/2$ g. (g is the acceleration due to gravity -32.2ft/sec^2).



Total Dynamic Head: Total dynamic head (TDH) is a theoretical distance. It is the static head, velocity head and headloss required to get the water from one point to another.
The horsepower output of an electric motor is directly reflected to the amperage that the motor draws. Any increase in horsepower requirements will give a corresponding increase in amperage.
Cavitation: Cavitation in pumps is the rapid creation and subsequent collapse of air bubbles occuring as a result of the inlet pressure falling below the design inlet pressure or when the pump is operating at a flow rate higher than the design flow rate. This collapse of the air bubbles typically manifests as a pinging or crackling noise. Cavitation is undesirable because it can damage the impeller, cause noise and vibration, and decrease pump efficiency.

18.2 Pumping Rate Calculations

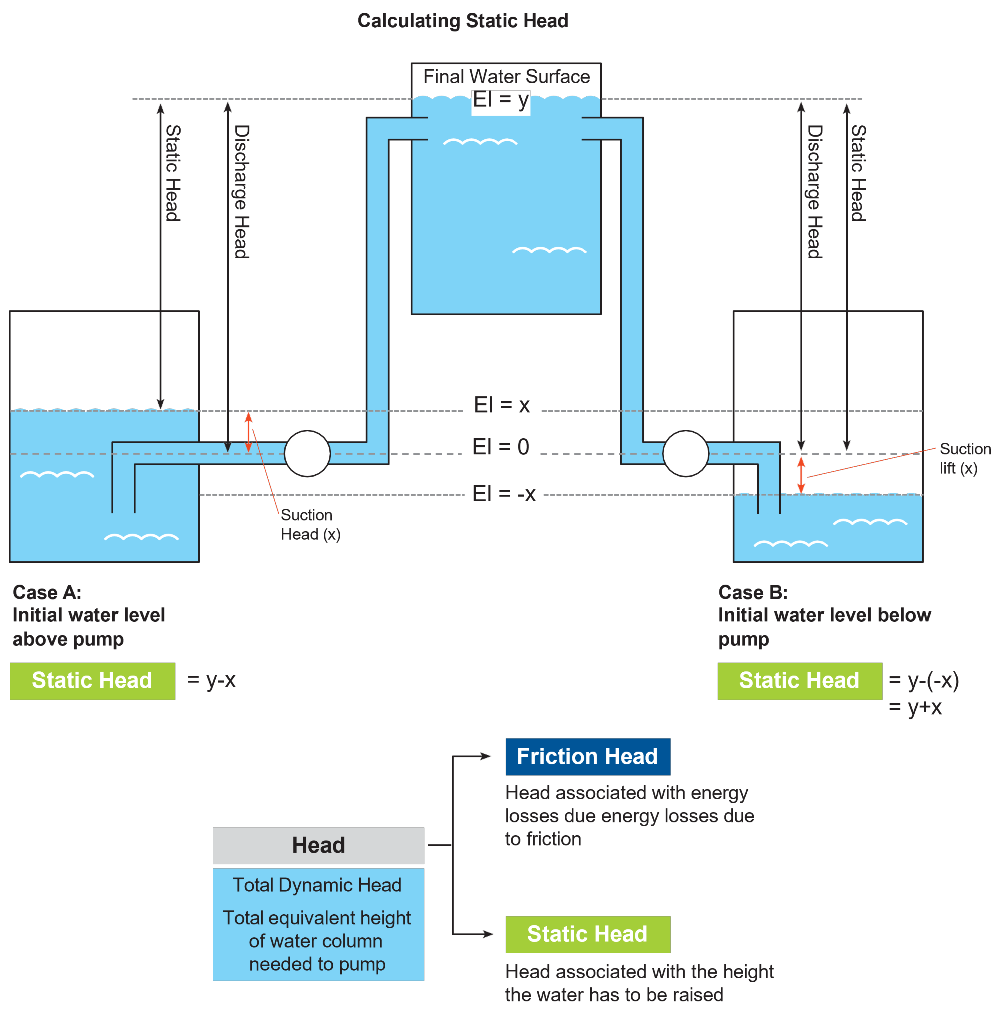
- For calculating volume pumped given the pump flow rate: Multiply the pump flow rate by the time interval
  Make sure:
  - The time units - in the given time interval and in the pump flow rate match
- For calculating time to pump a certain volume:
  1. Calculate the total volume pumped
  2. Divide the total volume by the pump flow rate

  Make sure:
  - The volume units - in the volume that needs to be pumped and in the pump flow rate match
  - The time unit in the pump flow rate needs to be converted to the time unit that you need the answer in

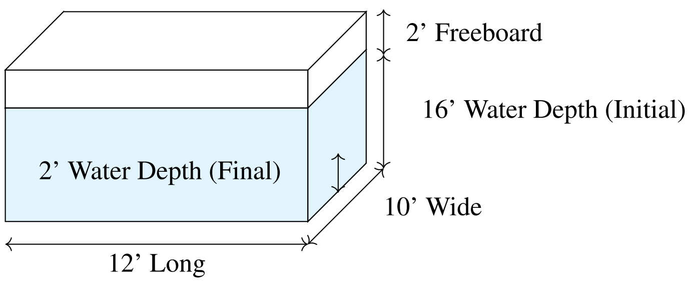
Example 1: A pump is set to pump 5 minutes each hour. It pumps at the rate of 35 gpm. How many gallons of water are pumped each day?
Solution:
$$\frac{35\ gal\ \ sludge}{\cancel{min}} * \frac{5\ \cancel{min}}{\cancel{hr}} * \frac{24\ \cancel{hr}}{day} = \boxed{\frac{4,200\ \ gallons}{day}}$$

Example 2: A pump operates 5 minutes each 15 minute interval. If the pump capacity is 60 gpm, how many gallons are pumped daily?
$$\frac{60\ \ gal\ \ sludge}{\cancel{min}} * \frac{5\ \cancel{min}}{15\ \ \cancel{min}} * 1440\frac{\cancel{min}}{day} = \boxed{\frac{28,800\ \ gal\ \ sludge}{day}}$$

Example 3: Given the tank is 10ft wide, 12 ft long and 18 ft deep tank including 2 ft of freeboard when filled to capacity. How much time (minutes) will be required to pump down this tank to a depth of 2 ft when the tank is at maximum capacity using a 600 GPM pump



Solution:



Volume to be pumped=12 $ft * 10 \; ft * (16-2) \; ft = 1,680 ft^3$

$$\Longrightarrow \frac{1,680\cancel{ft^3} * 7.48\frac{\cancel{gal}}{\cancel{ft^3}}}{600\frac{\cancel{gal}}{min}} = \boxed{21 min}$$

18.3 Pumping Head Calculations

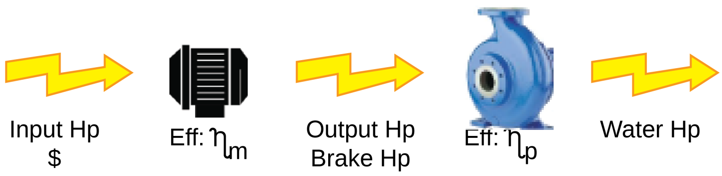
- A reservoir is 40 feet tall. Find the pressure at the bottom of the reservoir.
  $40\text{ft} \times 0.433\text{psi/ft} = 17.3\text{psi}$

- Find the height of water in a tank if the pressure at the bottom of the tank is 12 psi.
  $12\text{psi} \div 0.433\text{psi/ft} = 27.7\text{ft}$

- If a pump discharge pressure gauge read 10 psi, the height of the water corresponding to this pressure would be:

$$10 \ \ psi \times \frac{2.31 \ \ ft}{psi} = 23.1 \ \ ft$$

18.4 Power Requirements for Pumping



Where:

- **Input Hp** is the input power to the motor which produces the **Output Hp or Brake Hp** - the mechanical power which runs the pump.
- The ratio of Output Hp and Input Hp is the motor efficiency - η_m.
- The Output Hp is the input power (Brake Hp) to the pump to pump the water.
- Water Hp is the rate of energy transferred to the water being pumped and can be calculated by the formula:

$$\frac{\text{H} \ - \ \text{Head of water (ft)} \ * \ \text{Q} \ - \ \text{Flow (GPM)}}{3,960 \ \text{(Conversion factor for converting GPM} - \text{ft to Hp)}}$$

- The ratio of Output Hp and Water Hp is the pump efficiency - η_p.

18.5 Example Problems

1. 1 MGD is pumped against a 14' head. What is the water Hp? The pump mechanical efficiency is 85%. What is the brake horsepower?

   water Hp = flow * head

$$\frac{1,000,000 \ \ gal}{day} * \frac{day}{1440 \ \ min} * 14 \ \ ft * \frac{Hp}{3,960 \ \ GPM - ft} = \boxed{Water \ \ Hp = 2.46 \ \ Hp}$$

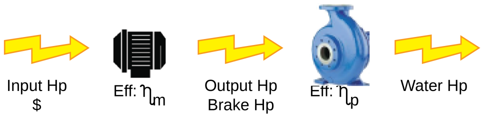
   pump Hp = brake Hp * pump efficiency

$$Brake \ \ Hp = \frac{2.46}{0.85} = \boxed{Brake \ \ Hp = 2.89Hp}$$

2. A flow of 200 gpm is pumped against a total head of 4.0 feet. The pump is 78% efficient and the motor' is 90% efficient. Calculate the input Hp.

   water Hp = flow * head

$$200GPM * 4ft * \frac{Hp}{3,960GPM - ft} = 0.2Hp$$



water Hp=brake Hp*pump efficiency, and
brake Hp=input Hp*motor efficiency
Therefore, water Hp=input Hp*motor efficiency*pump efficiency

$$\text{input Hp}=\frac{water\ \ Hp}{motor\ \ efficiency * pump\ \ efficiency} = \frac{0.2}{0.9 * 0.78} = \boxed{0.28Hp}$$

19 Sedimentation

1. Hydraulic or Surface Loading Rate - measures how rapidly wastewater moves through the sedimentation tank or clarifier. It is measured in terms of the number of gallons flowing each day through one square foot surface area of the clarifier.

   The hydraulic or surface loading rate

   $$Clarifier\ \ hydraulic\ \ loading\ \left(\frac{gpd}{ft^2}\right) = \frac{Clarifier\ \ influent\ \ flow(gpd)}{Clarifier\ \ surface\ \ area(ft^2)}$$

   Rectangular clarifier surface area = width * length
   Circular clarifier surface area = 0.785 * Diameter^2

2. Detention Time - it is the length of time that water stays in the sedimentation tank. It is also the time it takes for a unit volume of water to pass entirely through it.

   $$Clarifier\ \ detention\ \ time\ \ (hr) = \frac{Clarifier\ \ volume(cu.ft\ \ or\ \ gal)}{Influent\ \ flow\ \ (cu.ft\ \ or\ \ gal)/hr)}$$

   Rectangular clarifier volume = width * length * depth of water
   Circular clarifier volume = 0.785 * Diameter^2 * depth of water
   Typically volume is calculated in cu. ft and influent flow is given in gallons. Use 7.48 gal/ft^3 conversion factor to convert volume in cu. ft to gallons.

3. Overflow Rate - The weirs at the end of the sedimentation basin allow for the even distribution of the the outlet flow across the entire length of the weir. An adequate length of weir is needed to ensure smooth and even flow of water over the weirs. Weir overflow rate measures the number of gallons of water per day flowing over one foot of weir.

   $$Weir\ \ over\ \ flow\ \ rate\left(\frac{gpd}{ft}\right) = \left(\frac{Clarifier\ \ influent\ \ flow(gpd)}{Total\ \ effluent\ \ weir\ \ length\ \ (ft)}\right)$$

   Circular clarifier weir length = 3.14 * Diameter
   Example problem for (a), (b) and (c) above:

   A circular clarifier receives a flow of 5 MGD. If the clarifier is 90 ft. in diameter and is 12 ft. deep, what is: a) the hydraulic/surface loading rate, b) clarifier detention time in hours, and c) weir overflow rate?

   a) Hydraulic/surface loading rate:

   $$Clarifier\ \ hydraulic\ \ loading\ \left(\frac{gpd}{ft^2}\right) == \frac{\frac{5\cancel{MG}}{day} * \frac{10^6 gal}{\cancel{MG}}}{0.785 * 90^2 ft^2} = \boxed{786gpd/ft^2}$$

   b) Clarifier detention time:

   $$Clarifier\ \ detention\ \ time\ \ (hr) = \frac{Clarifier\ \ volume(cu.ft\ \ or\ \ gal)}{Influent\ \ flow\ \ (cu.ft\ \ or\ \ gal)/hr)}$$

$$Clarifier\ detention\ time\ (hr) = \frac{(0.785*90^2*12)\cancel{ft^3}}{\frac{5\cancel{MG}}{\cancel{day}}*\frac{10^6\cancel{gal}}{\cancel{MG}}*\frac{\cancel{ft^3}}{7.48\cancel{gal}}*\frac{\cancel{day}}{24hrs}} = \boxed{2.7hrs}$$

c) Overflow rate:

$$Weir\ overflow\ rate\left(\frac{gpd}{ft}\right) = \frac{\frac{5\cancel{MG}}{day}*\frac{10^6 gal}{\cancel{MG}}}{3.14*90ft} = \boxed{17{,}692\text{gpd/ft}}$$

20 Filtration

Filtration process typically involves following types of calculations:

1. Filter Flow Rates – the flow rate expressed in gpm can be calculated from the total flow over certain time or vice-versa can be used for determining either the time it would take to process a certain flow or calculate the total flow.
Example Problem: A filter box is 20 ft by 30 ft (including the sand area). If the influent valve is shut, the water drops 3 inches per minute. What is the rate of filtration in MGD?

$$\text{Filter flow rate=}\left((20\ \text{ ft}\times 30ft)ft^2*\frac{3\ \text{ in}}{\text{min}}*\frac{\text{ft}}{12\ \text{ in}}\right)\text{ft}^3*\frac{7.48\ \text{ gal}}{\text{ft}^3} = \boxed{1{,}122\ \text{ gpm}}$$

2. Filtration Rates – It is the gallons of water filtered per minute through each square foot of filter area. It generally ranging from 2 to 10gpm/ft^2.
Filtration rate is determined by the following equation:

$$\text{Filtration rate, gpm/ft}^2 = \frac{\text{Flow rate, gpm}}{\text{Filter surface area, ft}^2}$$

Example Problem: A filter 28ft long by 18ft wide treats a flow of 3.5MGD. What is the filtration rate in gpm/ft ^{2} ?

Approach: The flow will need to be converted to gpm and the surface area calculated in feet.

$$\text{Filtration rate, gpm/ft}^2 = \frac{\frac{3.5\ \cancel{MG}}{\cancel{day}}*\frac{1{,}000{,}000\ \ gal}{\cancel{MG}}*\frac{\cancel{day}}{1440\text{min}}}{28\ \ ft*18\ \ feet} = \boxed{4.8\ \ gpm/ft^2}$$

3. Backwashing Rates - is the amount of water, in gallons, required for each backwash. This is analogous to the Filter Flow Rate.
Example Problem: A filter has the following dimensions: 30ft long by 20ft wide with a depth of 24 inches of filter media. Assuming that a backwash rate of 15gal/ft^2/min is recommended and 10 minutes of backwash is required, calculate the amount of water, in gallons, required for each backwash.
The backwashing rate given in $gal/ft^2/min$ will need to be converted into gallons by multiplying it with the area (to eliminate ft^2 and by the backwash time in minutes

$$\text{Backwashing rate (gal)} = 15\frac{gal}{\cancel{ft^2}-\cancel{min}}*(30\text{ft}\times 20\text{ft})\cancel{ft^2}*10\ \ \cancel{min} = \boxed{90{,}000\ \ \text{gal}}$$

4. Backwash Rinse Rates - it is the upward velocity of the water during backwashing, expressed as in/min rise. To convert from gpm/ft^2 backwash rate to an in/min rise rate, use either of the following equations:

$$\text{Backwash rinse rate, in/min} = \frac{\text{Backwash rate, gpm/ft}^2\times 12\text{in/ft}}{7.48\text{gal/ft}^3}$$

Example Problem A filter 22ft long by 12ft wide has a backwash rate of 3260gpm. What is this backwash rate expressed as a in/min rise?

$$\text{Backwash rinse rate, in/min} = \frac{\text{Backwash rate, gpm}/\text{ft}^2 \times 12\text{in}/\text{ft}}{7.48\text{gal}/\text{ft}^3}$$

Based upon the above formula, the Backwash tate in gpm/ft^2 needs to be calculated by dividing the gpm flow by the surface area

$$\text{Backwash Rinse Rate, in/min} = \frac{\left(\frac{3260\text{gpm}}{22\text{ft} \times 12\text{ft}}\right)\text{gpm}/\text{ft}^2 \times 12\text{in}/\text{ft}}{7.48\text{gal}/\text{ft}^3} = \boxed{19.7 in/min}$$

5. Percent Product Water Used for Backwashing - the equation for percent of product water used for backwashing calculations used is:

$$\text{Backwash water, \%} = \frac{\text{Backwash water, gal}}{\text{Water filtered, gal}} \times 100$$

Example Problem A total of $11,400,000$ gal of water was filtered during a filter run. If backwashing used 48,500 gal of this product water, what percent of the product water is used for backwashing?

$$\text{Backwash water, \%} = \frac{48,500 \text{ gal}}{11,400,000 \text{ gal}} \times 100 = \boxed{0.43\%}$$

Practice Problems - Fractions

1. Convert $22\frac{1}{4}$ into a fraction
2. Express 10ft, 6in into fraction
3. Express 10ft, 6in into decimal

Practice Problems - Decimals and Powers of Ten

1. Write the equivalent of 10,000,000 as a power of ten
2. Find the product of $3.4564 * 10^2$
3. Find the product of $534.567 * 10^{-2}$
4. Find the value of $\frac{165.93}{10^{-2}}$
5. Find the value of $0.023 * 10^4$

Solutions:

1. 10^7
2. 345.64
3. 5.34567
4. 16,593
5. 230

Practice Problems - Rounding and Significant Digits

Round the following to the nearest hundredths (the second place after the decimal).
A. 2.4568
B. 27.2534
C. 128.2111
D. 364.8762
E. 354.777777
F. 34.666666
G. 67.33333

Solution:
A. 2.46
B. 27.25
C. 128.21
D. 364.88
E. 354.78
F. 34.67
G. 67.33
Round the following to the nearest tenths (the first place after the decimal).
A. 2.4568
B. 27.2534
C. 128.2111
D. 364.8762
E. 354.777777
F. 34.666666
G. 67.33333 Solution:
A. 2.5
B. 27.3
C. 128.2
D. 364.9
E. 354.8
F. 34.7
G. 67.3

Round the following answers off to the most significant digit.

	Problem	Accurate Answer
A.	$25.1 + 26.43 = 51.53$	
B.	$128.456 - 121.4 = 7.056$	
C.	$85 - 7.92432 = 77.07568$	
D.	$8.564 + 5 = 13.564$	

	Problem	Accurate Answer
A.	$26.34 \times 124.34567 = 3,275.26495$	
B.	$23.58 \times 34.251 = 807.63858$	
C.	$12,453/13.9 = 895.8992805755$	
D.	$12,457.92 \times 3 = 37,373.76$	

Practice Problems - Averages

1. Find the average of the following set of numbers:

0.2

0.2

0.1

0.3

0.2

0.4

0.6

0.1

0.3

2. The chemical used for each day during a week is given below. Based on these data, what was the average lb/day chemical used during the week?

Monday	92 lb/day
Tuesday	93 lb/day
Wednesday	98 lb/day
Thursday	93 lb/day
Friday	89 lb/day
Saturday	93 lb/day
Sunday	97 lb/day

3. The average chemical use at a plant is 77 lb/day. If the chemical inventory is 2800 lbs, how many days supply is this?

Practice Problems - Percentage

1. 25% of the chlorine in a 30 -gallon vat has been used. How many gallons are remaining in the vat?
2. The annual public works budget is $147,450. If 75% of the budget should be spent by the end of September, how many dollars are to be spent? How many dollars will be remaining?
3. A 75 pound container of calcium hypochlorite has a purity of 67%. What is the total weight of the calcium hypochlorite?
4. $3/4$ is the same as what percentage?
5. A 2% chlorine solution is what concentration in mg/L ?
6. A water plant produces 84,000 gallons per day. 7,560 gallons are used to backwash the filter. What percentage of water is used to backwash?
7. The average day winter demand of a community is 14,500 gallons. If the summer demand is estimated to be 72% greater than the winter, what is the estimated summer demand? Demand - When related to use, the amount of water used in a period of time. The term is in reference to the "demand" put onto the system to meet the need of customers.
8. The master meter for a system shows a monthly total of 700,000 gallons. Of the total water, 600,000 gallons were used for billing. Another 30,000 gallons were used for flushing. On top of that, 15,000 gallons were used in a fire episode and an estimated 20,000 gallons were lost to a main break that was repaired that same day. What is the total unaccounted for water loss percentage for the month?
9. Your water system takes 75 coliform tests per month. This month there were 6 positive samples. What is the percentage of samples which tested positive?

$$Time = \frac{Total\ \ volume\ \ to\ \ be\ \ pumped}{Pump\ \ flow\ \ rate}$$

$$\Longrightarrow \frac{(0.785*110^2*25)\cancel{ft^3}*\dfrac{7.48\cancel{gal}}{\cancel{ft^3}}}{\dfrac{1420\cancel{gal}}{min}} = \boxed{1,251\ \ min}$$

Practice Problems - Ratio and Proportion

1. It takes 6 gallons of chlorine solution to obtain a proper residual when the flow is 45,000 gpd. How many gallons will it take when the flow is 62,000 gpd?
2. A motor is rated at 41 amps average draw per leg at 30Hp. What is the actual Hp when the draw is 36 amps? C.
3. If it takes 2 operators 4.5 days to clean an aeration basin, how long will it take three operators to do the same job?
4. It takes 3 hours to clean 400 feet of collection system using a sewer ball. How long will it take to clean 250 feet?
5. It takes 14 cups of HTH to make a 12% solution, and each cup holds 300 grams. How many cups will it take to make a 5% solution?

Solution

1. The gallons chlorine and flow are directly related.

   Thus,
   $$\frac{6}{45,000} = \frac{X}{62,000} \Longrightarrow X = \frac{6*62,000}{45,000} = 8.3\text{gallons}$$

2. The amp draw and Hp are directly related.

   This
   $$\frac{30}{41} = \frac{X}{36} \Longrightarrow X = \frac{30*36}{41} = 26.3\text{Hp}$$

3. The number of operators and the days to clean are inversely related.

   Thus,
   $$2*4.5 = 3*X \Longrightarrow X = \frac{2*4.5}{3} = 3\text{days}$$

4. The hours to clean and the length of system cleaned are directly proportional.

   Thus,
   $$\frac{3}{400} = \frac{X}{250} \Longrightarrow X = \frac{3*250}{400} = 1.9\text{hours}$$

5. The cups of HTH and percentage HTH solution are directly propoirtional.

   Thus,

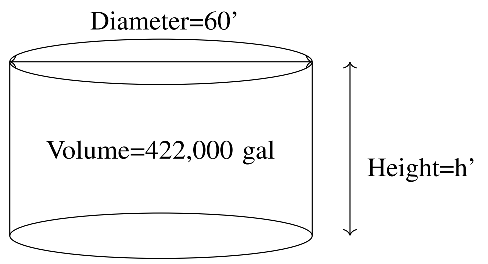
   $\frac{14}{12} = \frac{X}{5} \implies X = \frac{14*5}{12} = 5.8\text{cups}$

Practice Problems - Area and Volume

1. A 60-foot diameter tank contains 422,000 gallons of water. Calculate the height of water in the storage tank.
2. What is the volume of water in ft^3, of a sedimentation basin that is 22 feet long, and 15 feet wide, and filled to 10 feet?
3. What is the volume in ft^3 of an elevated clear well that is 17.5 feet in diameter, and filled to 14 feet?
4. What is the area of the top of a storage tank that is 75 feet in diameter?
5. What is the area of a wall 175ft. in length and 20ft. wide?
6. You are tasked with filling an area with rock near some of your equipment. 1 Bag of rock covers 250 square feet. The area that needs rock cover is 400 feet in length and 30 feet wide. How many bags do you need to purchase?
7. A circular clearwell is 150 feet in diameter and 40 feet tall. The Clearwell has an overflow at 35 feet. What is the maximum amount of water the clearwell can hold in Million gallons rounded to the nearest hundredth?
8. A sedimentation basin is 400 feet length, 50 feet in width, and 15 feet deep. What is the volume expressed in cubic feet?
9. A clearwell holds $314,000\text{ft}^3$ of water. It is 100ft in diameter. What is the height of the clearwell?
10. A treatment plant operator must fill a clearwell with $10,000\text{ft}^3$ of water in 90 minutes. What is the rate of flow expressed in GPM?
11. A water tank has a capacity of 6MG. It is currently half full. It will take 6 hours to fill. What is the flow rate of the pump?
12. A clearwell with the capacity of 2.5MG is being filled after a maintenance period. The flow rate is 2,500 GPM. The operator begins filling at 7 AM. At what time will the clearwell be full?
13. A chemical feed pump with a 6-inch bore and a 6-inch stroke pumps 60 cycles per minute. Find the pumping rate in gpm.
14. Determine the flow capacity of a pump in gpm if the pump lowers the water level in a 6 -foot square wet well by 8 inches in 5 minutes.

Solution:

1. Volume = Surface area * height $\implies$ height $= \frac{\text{Volume}}{\text{Surface area}}$

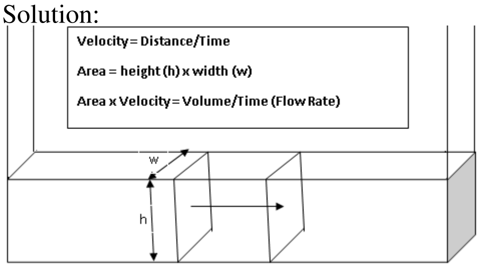
$$\Longrightarrow \text{height} = \frac{422,000\ \cancel{gal} * \dfrac{\cancelto{ft}{ft^3}}{7.48\ \cancel{gal}}}{0.785 * 60^2\ \cancel{ft^2}} = \boxed{101\ \ ft}$$

Practice Problems - Flow and Velocity

1. A rectangular channel 3 ft. wide contains water 2 ft. deep flowing at a velocity of 1.5 fps. What is the flow rate in cfs?
2. Flow in an 8-inch pipe is 500 gpm. What is the average velocity in ft/sec? (Assume pipe is flowing full)
3. A pipeline is 18" in diameter and flowing at a velocity of 125 ft. per minute. What is the flow in gallons per minute?
4. The velocity in a pipeline is 2 ft./sec. and the flow is 3,000 gpm. What is the diameter of the pipe in inches?
5. Find the flow in a 4-inch pipe when the velocity is 1.5 feet per second.
6. A 42-inch diameter pipe transfers 35 cubic feet of water per second. Find the velocity in ft/sec.
7. A plastic float is dropped into a channel and is found to travel 10 feet in 4.2 seconds. The channel is 2.4 feet wide and 1.8 feet deep. Calculate the flow rate of water in cfs.
8. The flow velocity of a 6-inch diameter pipe is twice that of a 12-inch diameter pipe if both are carrying 50 gpm of water. True or false?
9. What should the flow meter read in gpm if a 4-inch diameter main is to be flushed at a velocity of 4.6 fps?
10. The velocity through a channel is 4.18 fps. If the channel is 4 feet wide by 2 feet deep by 10 feet long, what is the flow rate in gpm?
11. What is the average flow velocity in ft/sec for a 12-inch diameter main carrying a daily flow of 2.5mgd ?

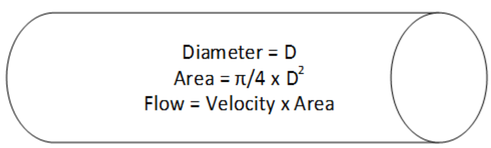
Solution:

1. Solution:



$$Q = V * A \Longrightarrow Q = 1.5\frac{ft}{sec} * (3*2)ft^2 = \boxed{9\frac{ft^3}{sec}}$$

2. Solution:



$Q = V * A$

$$\implies V = \frac{Q}{A} \implies V\left(\frac{ft}{s}\right) = \frac{\frac{500\cancel{gallon}}{\cancel{min}} * \frac{\cancel{ft^3}^{\,ft} * \frac{min}{60sec}}{7.48\cancel{gal}}}{0.785 * \left(\frac{8}{12}\right)^2 \cancel{ft^2}} = \boxed{3.2ft/s}$$

3. Solution:

   The diameter of the pipe is 4 inches. Therefore, the radius is 2 inches. Convert the 2 inches to feet.
   $\frac{2}{12} = 0.6667\text{ft}$
   $\text{A} = \pi \times \text{r}^2$
   $\text{A} = \pi \times (0.167\text{ft})^2$
   $\text{A} = \pi \times 0.028\text{ft}^2$
   $\text{A} = 0.09\text{ft}^2$
   $\text{Q} = \text{V} \times \text{A}$
   $\text{Q} = 1.5\text{ft/sec} \times 0.09\text{ft}^2$
   $\text{Q} = 0.14\text{ft/3sec(cfs)}$

Practice Problems - Unit Conversions

Convert the following:

1. Convert 1000 ft^3 to cu. yards
2. Convert 10 gallons/min to ft^3/hr
3. Convert 100,000 ft^3 to acre-ft.
4. Find the flow in gpm when the total flow for the day is 65,000 gpd.
5. Find the flow in gpm when the flow is 1.3cfs.
6. Find the flow in gpm when the flow is 0.25cfs.
7. The flow rate through a filter is 4.25 MGD. What is this flow rate expressed as gpm?
8. After calibrating a chemical feed pump, you've determined that the maximum feed rate is 178 mL/ minute. If this pump ran continuously, how many gallons will it pump in a full day?
9. A plant produces 2,000 cubic foot of water per hour. How many gallons of water is produced in an 8-hour shift?

Solution

1. Solution:
   $1000\cancel{ft^3} * \frac{cu.yards}{27\cancel{ft^3}} = 37cu.yards$

2. Solution:

$$\frac{10\ \cancel{\text{gallons}}}{\cancel{\text{min}}} * \frac{\text{ft}^3}{7.48\cancel{\text{gallons}}} * \frac{60\cancel{\text{min}}}{\text{hr}} = \frac{80.2\ \text{ft}^3}{\text{hr}}$$

3. Solution:

$$100,000\cancel{ft^3} * \frac{acre - ft}{43,560\cancel{ft^2 - ft}} = 2.3 acre - ft$$

Note: From the conversion table: acre = 43,560 ft^2
Thus, acre-ft = 43,560 ft^2-ft or 43,560 ft^3

4. Solution:

$$\frac{65,000\text{gpd}}{1,440\ \text{min/day}} = 45\text{gpm}$$

5. Solution:
$$1.3\frac{\text{cfs}}{1}\text{x}\frac{448\text{gpm}}{1\text{cfs}} = 582\text{gpm}$$

6. Solution:

$$0.25\frac{\text{cfs}}{1} \times \frac{448\text{gpm}}{1\text{cfs}} = 112\text{gpm}$$

7. Solution:
$$Flowrate, gpm = \frac{Flow\ \ rate,\ \ gpd}{1440\ \ min/day}$$
Note: We are assuming that the filter operated uniformly over that 24 hour period.

$$Flowrate, gpm = \frac{4.25\ \frac{\cancel{MG}}{\cancel{day}} * 1,000,000\ \ \frac{gal}{\cancel{MG}}}{1440\frac{min}{\cancel{day}}} = \boxed{2,951\ \ gpm}$$

8. Solution:

$$\frac{2000\ \cancel{ft^3}}{\cancel{hr}} * \frac{7.48\ \ \text{gallons}}{\cancel{ft^3}} * \frac{60\ \cancel{hr}}{\text{shift}} = \boxed{\frac{119,680\ \ \text{gallons}}{\text{shift}}}$$

Practice Problems - Concentration

1. What is the concentration in mg/l of 4.5% solution of that substance.

2. How many lbs of salt is needed to make 5 gallons of a 25mg/l solution

Practice Problems - Density and Specific Gravity

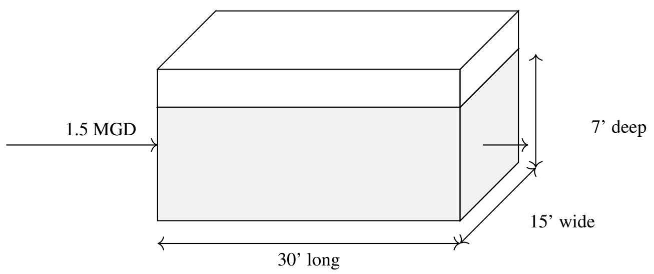
1. What is the specific gravity of a 1 ft^3 concrete block which weighs 145 lbs?
2. What is the specific gravity of a chlorine solution if 1 (one) gallon weighs 10.2lbs?
3. How much does each gallon of zinc orthophosphate weigh (pounds) if it has a specific gravity of 1.46?
4. How much does a 55 gallon drum of 25% caustic soda weigh (pounds) if the specific gravity is 1.28?

Practice Problems - Detention Time

1. A flocculation basin is 7 ft deep, 15 ft wide, and 30 ft long. If the flow through the basin is 1.35 MGD, what is the detention time in minutes?
2. A tank has a diameter of 60 feet with an overflow depth at 44 feet. The current water level is 16 feet. Water is flowing into the tank at a rate of 250 gallons per minute. At this rate, how many days will it take to fill the tank to the overflow?
3. How long will it take to fill a 50 gallon hypochlorite tank if the flow is 5gpm ?
4. Find the detention time in a 45,000 gallon reservoir if the flow rate is 85gpm.
5. If the fuel consumption to the boiler is 35 gallons per day. How many days will the 500 gallon tank last.
6. The sedimentation basin on a water plant contains 5,775 gallons. What is the detention time if the flow is 175gpm.

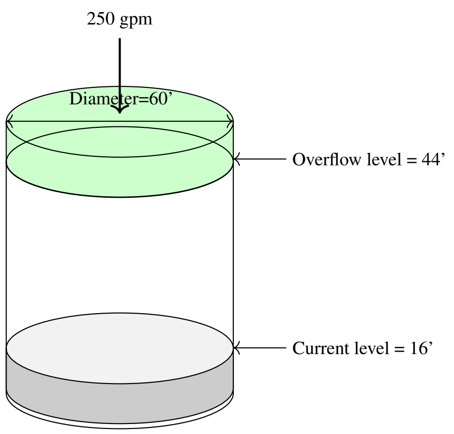
Solution

1. Solution:



$$\mathrm{DT} = \frac{(30*15*7)\mathrm{ft}^3 * 7.48\frac{gal}{ft^3}}{1,350,000\frac{\mathrm{gal}}{day} * \frac{\mathrm{day}}{1440\mathrm{min}}} = 25\mathrm{min}$$

2. Solution:



$$\text{Fill time} = \frac{Volume}{Flow} = \frac{0.785 * 60^2 * (44-16) ft^3 * \frac{7.48 gallons}{ft^3}}{250\frac{gallons}{min} * \frac{1440\ min}{day}} = 1.6\ days$$

3. Solution:
   4

4. Solution:
   5

   $$\text{DT} = \frac{50\text{gal}}{5\text{gal/min}} = 10 \text{ min}$$

5. Solution:

   $$\text{DT} = \frac{45,000\text{gal}}{85\text{gal/min}} = 529 \text{ min} \quad \text{or} \quad \frac{529 \text{ min}}{60 \text{ min/hr}} = 8.8\text{hrs}$$

6. Solution:

   $$\text{DT} = \frac{500 \text{ gal}}{35\text{gal/ day}} = 14.3 \text{ days}$$

7. Solution:

   $$\text{DT} = \frac{5,775\text{gal}}{175\text{gal/min}} = 33 \text{ min}$$

Practice Problems - Pounds Formula

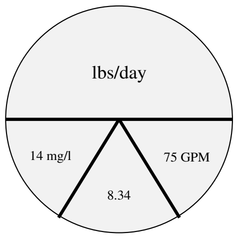
1. A water treatment plant operates at the rate of 75 gallons per minute. They dose soda ash at 14 mg/L. How many pounds of soda ash will they use in a day?

2. A water treatment plant is producing 1.5 million gallons per day of potable water, and uses 38 pounds of soda ash for pH adjustment. What is the dose of soda ash at that plant?

3. A water treatment plant produces 150,000 gallons of water every day. It uses an average of 2 pounds of permanganate for iron and manganese removal. What is the dose of the permanganate?
4. A water treatment plant uses 8 pounds of chlorine daily and the dose is 17 mg/l. How many gallons are they producing?
5. An operator mixes 40 lb of lime in a 100-gal tank containing 80 gal of water. What is the percent of lime in the slurry?
6. A treatment plant has a maximum output of 30MGD and doses ferric chloride at 75 mg/L. How many pounds of Ferric Chloride does the plant use in a day?
7. A treatment plant uses 750 pounds of alum a day as it treats 15MGD. What was the dose rate?
8. A treatment plant operates at 1,500 gallons a minute and uses 500 pounds of alum a day. What is the alum dose?

Solution:

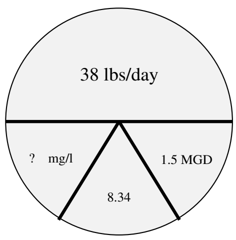
1. Solution:



$$\frac{\text{lbs}}{\text{day}} = \text{Flow}\frac{\text{MG}}{\text{day}} * \text{Concentration}\frac{\text{mg}}{\text{l}} * 8.34$$

$$\frac{\text{lbs}}{\text{day}} = 75\frac{\cancel{\text{gallons}}}{\cancel{\text{min}}} * 1440\frac{\cancel{\text{min}}}{\text{day}} * \frac{\text{MG}}{1,000,000\ \cancel{\text{gallons}}} * 250\frac{\text{mg}}{\text{l}} * 8.34 = \boxed{225\frac{lbs}{day}}$$

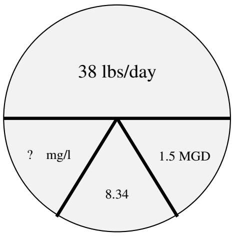
2. Solution:



$$\frac{\text{lbs}}{\text{day}} = \text{Flow}\frac{\text{MG}}{\text{day}} * \text{Concentration}\frac{\text{mg}}{\text{l}} * 8.34 \implies \text{Concentration}\frac{\text{mg}}{\text{l}} = \frac{\frac{\text{lbs}}{\text{day}}}{\text{Flow}\frac{\text{MG}}{\text{day}} * 8.34}\ \text{Concentration}\frac{\text{mg}}{\text{l}} =$$

$$\frac{38\frac{\text{lbs}}{\text{day}}}{1.5\frac{\text{MG}}{\text{day}} * 8.34} = \boxed{3\frac{\text{mg}}{\text{l}}}$$

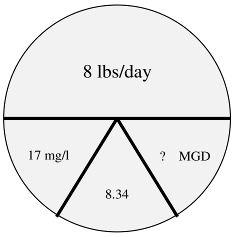
3. Solution:



$$\frac{\text{lbs}}{\text{day}} = \text{Flow}\frac{\text{MG}}{\text{day}} * \text{Concentration}\frac{\text{mg}}{\text{l}} * 8.34 \implies \text{Concentration}\frac{\text{mg}}{\text{l}} = \frac{\frac{\text{lbs}}{\text{day}}}{\text{Flow}\frac{\text{MG}}{\text{day}} * 8.34} \; \text{Concentration}\frac{\text{mg}}{\text{l}} =$$

$$\frac{2\frac{\text{lbs}}{\text{day}}}{\left(150,000\frac{\cancel{\text{Gallons}}}{\text{day}} * \frac{\text{MG}}{1,000,000\ \cancel{\text{Gallons}}} * 8.34\right)} = \boxed{3\frac{\text{mg}}{\text{l}}}$$

4. Solution:



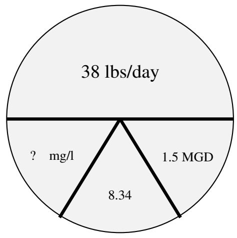
$$\frac{\text{lbs}}{\text{day}} = \text{Flow}\frac{\text{MG}}{\text{day}} * \text{Concentration}\frac{\text{mg}}{\text{l}} * 8.34$$

$$\implies \text{Flow}\frac{\text{MG}}{day} = \frac{\frac{\text{lbs}}{\text{day}}}{\text{Concentration}\frac{\text{mg}}{\text{l}} * 8.34} = \frac{8\frac{\text{lbs}}{\text{day}}}{17\frac{\text{mg}}{\text{l}} * 8.34} = 0.056425\frac{\text{MG}}{day}$$

$$0.056425\frac{\text{MG}}{day} * \frac{1,000,000\ \text{Gallons}}{\text{MG}} = \boxed{56,425\ \text{Gallons}}$$

5. Solution:
$\text{lbs} = \text{Volume(MG)} * \text{Concentration}\frac{\text{mg}}{\text{l}} * 8.34$

$$\implies \text{Concentration}\frac{\text{mg}}{\text{l}} = \frac{\text{lbs}}{\text{Volume(MG)} * 8.34} = \frac{40\ \text{lbs}}{80\ \text{gallons} * \frac{\text{MG}}{1,000,000\ \cancel{\text{gallons}}} * 8.34}$$



Practice Problems - Temperature Conversion

1. Convert 22°C into degree Fahrenheit.
2. Convert 56°C into degree Celsius.

Practice Problems - Pressure-Force Relationship

1. Find the force on a 12-inch valve if the water pressure within the line is 60 psi. Express your answer in tons.

   Force = Pressure × Area

   $$\Longrightarrow 60 \ \frac{\text{lbs}}{\text{in}^2} * 0.785 * (12\text{in})^2 * \frac{1\text{ton}}{2000\text{lbs}} = \boxed{3.39 \ \text{tons}}$$

2. A 42-inch main line has a shut off valve. The same line has a 10-inch bypass line with another shut-off valve. Find the amount of force on each valve if the water pressure in the line is 80 psi. Express your answer in tons.

   Force = Pressure × Area

   Calculating the force from the 42" line on the shutoff valve:

   $$\Longrightarrow 80 \ \frac{\text{lbs}}{\text{in}^2} * 0.785 * (42\text{in})^2 * \frac{1\text{ton}}{2000\text{lbs}} = \boxed{55 \ \text{tons}}$$

   Calculating the force from the 10" line on the shutoff valve:

   $$\Longrightarrow 80 \ \frac{\text{lbs}}{\text{in}^2} * 0.785 * (10\text{in})^2 * \frac{1\text{ton}}{2000\text{lbs}} = \boxed{3.14 \ \text{tons}}$$

3. A water tank is 15 feet deep and 30 feet in diameter. What is the force exerted on a 6-inch valve at the bottom of the tank?

   Force = Pressure × Area

   $$\Longrightarrow 15 \ \text{ft} * \frac{0.433 \ \text{psi}}{\text{ft}} * 0.785 * (6\text{in})^2 = \boxed{183 \ \text{lbs}}$$

Practice Problems - Wells

1. A well is drilled through an unconfined aquifer. The top of the aquifer is 80 feet below grade. After the well was in service for a year, the water level in the well stabilized at 110 feet below grade. What is the drawdown? $\text{DRAWDOWN} = \text{INITIDC} - \text{PUMPING} = 80\text{ft} - 110\text{ft} = 30\text{feet}$

2. A well produces 300 gpm. If the drawdown is 30 feet, find the specific yield.
   $\text{Specific Yield} = \frac{\text{Yield}}{\text{Drawdown}} = \frac{300\text{gpm}}{30\text{ft}} = 10\text{gpm}/\text{ft}$

3. The specific yield for a well is 10gpm/ft. If the well produces 550gpm, what is the drawdown?

   $\text{Specific Yield} = \frac{\text{Yield}}{\text{Drawdown}} \implies 10\text{gpm}/\text{ft} = \frac{550\text{gpm}}{\text{Drawdown}}$

   $\implies \text{Drawdown} = \frac{550}{10} = \boxed{55\text{ft}}$

4. The pumped water level of a well is 400 feet below the surface. The well produces 350 gpm. If the aquifer level is 250 feet below the surface, what is the specific yield for the well?

Practice Problems - Pumping Head

1. Convert 45 psi to feet of head

2. How long (in minutes) will it take to pump down 25 feet of water in a 110 ft diameter cylindrical tank when using a 1420 gpm pump

3. How long will it take (hrs) to fi

   ll a 2 ac-ft pond if the pumping rate is 400 GPM?

4. If the pressure at a water main is 50 psi, what would the static pressure (psi) be at a faucet on the top floor of a four story building? (Assuming 10 ft. per story)

Solution:

1. Solution:
   $$45\ \cancel{psi} * \frac{ft\ \ head}{0.433\cancel{psi}} = \boxed{92.4\text{ feet}}$$

2. Solution:
   $$Time\ \ to\ \ pump\ \ down = \frac{Volume}{Flow} = \frac{0.785 * 110^2 * 25\ \ \cancel{ft^3}}{1420\frac{\cancel{gallon}}{min} * \frac{\cancel{ft^3}}{7.48\cancel{gallon}}} = \boxed{190\ \ minutes}$$

3. Solution:
   $$Time\ \ to\ \ fill\ \ (hours) = \frac{Volume}{Flow} = \frac{2\ \ \cancel{Ac-ft} * \frac{325,851\ \ \cancel{gallons}}{\cancel{Ac-ft}}}{400\frac{\cancel{gallons}}{\cancel{min}} * \frac{60\ \ \cancel{min}}{hr}} = \boxed{27\ \ hours}$$

4. Solution:
   $$50psi - 4 * 10\ \ \cancel{ft} * \frac{0.433\cancel{psi}ft\ \ head}{=}\boxed{32.7\text{ psi}}$$

Practice Problems - Pumping Power Requirements

1. If a pump is operating at 2,200 gpm and 60 feet of head, what is the water horsepower? If the pump efficiency is 71%, what is the brake horsepower?

2. The water horsepower of a pump is 10Hp and the brake horsepower output of the motor is 15.4Hp. What is the efficiency of the pump?

3. The water horsepower of a pump is 25Hp and the brake horsepower output of the motor is 48Hp. What is the efficiency of the pump?

4. The efficiency of a well pump is determined to be 75%. The efficiency of the motor is estimated at 94%. What is the efficiency of the well?

5. If a motor is 85% efficient and the output of the motor is determined to be 10 BHp, what is the electrical horsepower requirement of the motor?

6. The water horsepower of a well with a submersible pump has been calculated at 8.2 WHp. The Output of the electric motor is measured as 10.3BHp. What is the efficiency of the pump?

7. Water is being pumped from a reservoir to a storage tank on a hill. The elevation difference between water levels is 1200 feet. Find the pump size required to fill the tank at a rate of 120 gpm. Express your answer in horsepower.

8. A 25hp pump is used to dewater a lake. If the pump runs for 8 hours a day for 7 days a week, how much will it cost to run the pump for one week? Assume energy costs $0.07 per kilowatt hour.

9. A pump station is used to lift water 50 feet above the pump station to a storage tank. The pump rate is 500gpm. If the pump has an efficiency of 85% and the motor has an efficiency of 90%, find each of the following: Water Horsepower, Brake Horsepower, Motor Horsepower, and Wire-to-Water Efficiency.

10. Find the brake horsepower for a pump given the following information: Total Dynamic Head = 75 feet, Pump Rate = 150 gpm, Pump Efficiency = 90%, Motor Efficiency = 85%

11. Water is being pumped from a reservoir to a storage tank on a hill. The elevation difference between water levels is 1200 feet. Find the pump size required to fill the tank at a rate of 120 gpm. Express your answer in horsepower.

Solutions:

1. Solution:

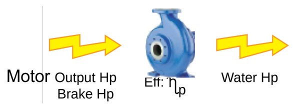
   water Hp = flow * head

   $$2,200GPM * 60ft * \frac{Hp}{3,960GPM-ft} = \boxed{Water\ \ Hp = 33.3Hp}$$

   pump Hp = brake Hp * pump efficiency

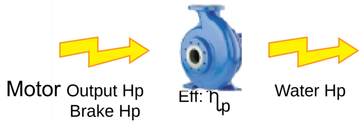
   $$brake\ \ Hp = \frac{33.3}{0.71} = \boxed{Brake\ \ Hp = 47Hp}$$

2. Solution:



$$\eta_p = \frac{10\text{BHp}}{15.4\text{EHp}} \times 100 = \boxed{65\%}$$

3. Solution:

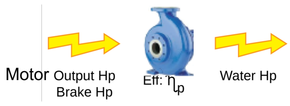


$$\eta_p = \frac{25 \ \text{Water Hp}}{48 \ \text{brake Hp}} \times 100 = \boxed{52\%}$$

4. Solution:

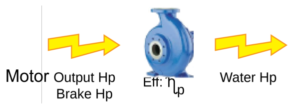
$$Well \ \ efficiency = \eta_m * \eta_p \implies 0.94 \times 0.75 = 0.705 \times 100 = \boxed{71\%}$$

5. Solution:



$$\frac{10\text{BHp}}{0.85} = \boxed{12\text{EHp or Input Hp}}$$

6. Solution:



$$\eta_p = \frac{8.2 \ \text{W Hp}}{10.3 \ \text{BHp}} \times 100 = \boxed{80\%}$$

7. Solution:

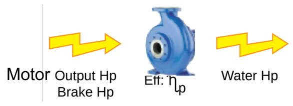
water Hp = flow * head

$$\text{Water Hp} = 120 \ \text{gpm} * 1,200 \ \ ft * \frac{\text{Hp}}{3,960 \ \text{gpm} - \text{ft}} = \boxed{37 \ \text{Hp}}$$

8. Solution:

$$25 \ \text{Hp} \frac{0.746 \ \text{kW}}{\text{Hp}} * \frac{8 \ \text{hrs}}{\text{day}} * \frac{7 \ \text{days}}{\text{month}} * \frac{\$0.07}{\text{kWh}} = \boxed{\frac{\$73.1}{\text{week}}}$$

9. Solution:



water Hp = flow * head

$$\text{Water Hp} = 500 \text{ gpm} * 50 \ ft * \frac{\text{Hp}}{3,960 \text{ gpm} - \text{ft}} = \boxed{6.3 \text{ WHp}}$$

$$\text{Pump efficiency} = \frac{\text{water Hp}}{\text{brake Hp}} \implies \text{brake Hp} = \frac{\text{pump Hp}}{\text{Pump efficiency}}$$

$$\text{brake } Hp = \frac{6.3}{0.85} = \boxed{7.4 \text{ Hp}}$$

$$\text{Motor efficiency} = \frac{\text{brake Hp}}{\text{input Hp}} \implies \text{input Hp} = \frac{\text{brake Hp}}{\text{motor efficiency}} = \frac{7.4}{0.9} = \boxed{8.2 \text{ Hp}}$$

$$\text{Wire} - \text{to} - \text{water efficiency} = \eta_m * \eta_p \implies 0.9 \times 0.85 \times 100 = \boxed{77\%}$$

10. Solution:

water Hp = flow * head

$$150 \text{ GPM} * 75\text{ft} * \frac{Hp}{3,960 GPM - ft} = \boxed{Water \ Hp = 2.8 Hp}$$

pump Hp = brake Hp * pump efficiency

$$brake \ Hp = \frac{2.8}{0.9} = \boxed{Brake \ Hp = 3.1 Hp}$$

Practice Problems - Chemical Dosing

1. Determine the chlorinator setting in pounds per day if a water plant produces 300gpm and the desired chlorine dose is 2.0mg/L.

2. The finished water chlorine demand is 1.2mg/L and the target residual is 2.0mg/L. If the plant flow is 5.6mgd, how many pounds per day of 65% hypochlorite solution will be required?

3. Fluoride is added to finished water at a dose of 4mg/L. Find the feed rate setting for a fluoride saturator in gal/min if the water plant produces 5mgd.

4. If chlorine costs $0.21 per pound, what is the daily cost to chlorinate a 5mgd flow rate at a dosage of 2.6mg/L ?

5. One gallon of sodium hypochlorite laundry bleach, with 5.25% available chlorine, contains how many pounds of active chlorine?

6. How much sodium hypochlorite, in gallons, is required to obtain a residual of 100mg/L in a well? The casing diameter is 18 -inches and the length is 80 feet. Sodium hypochlorite contains 5.25% available chlorine. Assume a demand of 15mg/L.

7. A water company uses an average of 600gpm of water. The water contains 0.30mg/L of manganese and 0.06mg/L of iron. How many pounds of iron and manganese are pumped into the distribution system each year?

8. How many pounds of copper sulfate will be needed to dose a reservoir with 0.6mg/L of copper? The reservoir holds 30 million gallons. The copper sulfate is 25% copper by weight.

9. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of aluminum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 9mg/L. Determine the setting on the liquid alum feeder in ml/min when the plant flow is 3.2mgd.

10. The raw water supply contains 1.8mg/L of fluoride. The flow rate is 400gpm. The target fluoride dose for the finished water is 3mg/L. Find the desired feed rate in gpm for a fluoride saturator.
11. The raw water alkalinity is 50mg/L as calcium carbonate. The water is treated by adding 15 mg/L of alum. What is the alkalinity of the finished water?

Solution:
Example 1: If a 5 MGD flow is to be dosed with 25 mg/l of a certain chemical, calculate the lbs/day that chemical required.
Solution
Applying lbs formula:

$$\frac{lbs}{day} = 5MGD * 250\frac{mg}{l} * 8.34 = \boxed{1,042\frac{lbs}{day}}$$

Example 2: Calculate the lbs of chemical in 7,500 gallons of 4.5% active solution of that chemical.
Solution
Applying lbs formula:

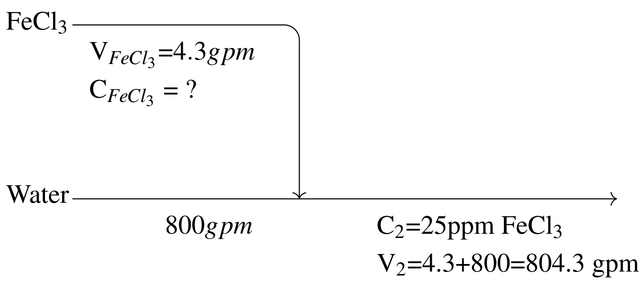
$$lbschemical = \frac{7500}{1,000,000}MG * 4.5 * 10,000 * 8.34 = \boxed{2,815\ \ lbs\ \ chemical}$$

Practice Problems - Blending and Dilution

1. Ferric chloride is being added as a coagulant to the raw water entering a plant. Sampling shows that the concentration of ferric in the raw water is 25 ppm. A quick check of the chemical metering pump shows that it is operating at a flow rate of 4.3 gpm. If the flow through the water plant is 800 gpm, what is the concentration of raw chemical in the dosing tank?
2. A water plant is fed by two different wells. The first well produces water at a rate of 600 gpm and contains arsenic at 0.5 mg/L. The second well produces water at a rate of 350 gpm and contains arsenic at 12.5 mg/L. What is the arsenic concentration of the blended water?
3. Liquid polymer is delivered as an 8 percent solution. How many gallons of liquid polymer should be mixed in a tank to produce 150 gallons of 0.6 percent solution?
4. There are two raw water lines feeding a water plant. One line carries a flow rate of 500 gpm with a TDS concentration of 1500 mg/L. The second line has a flow rate of 6 mgd with a a 250 mg/L TDS concentration. What is the actual combined TDS concentration entering the plant?

Solutions:

1. Solution:



$C_1 * V_1 = C_2 * V_2$

$C_{FeCl_3} * V_{FeCl_3} = C_2 * (V_{FeCl_3}+V_{Water})$

$C_{FeCl_3} * 4.3 = 25 * (804.3)$

$$C_{FeCl_3} = \frac{25 * (804.3)}{4.3} = \boxed{4,676\ \text{ppm or } 0.47\%}$$

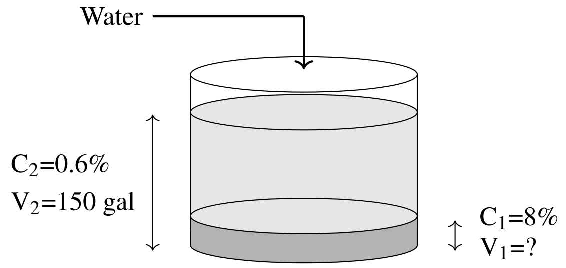
2. Solution:

$C_1 * V_1 + C_2 * V_2 + = C_3 * V_3 = C_3 * (V_1 + V_2)$

$C_{Well\ 1} * V_{Well\ 1} + C_{Well\ 2} * V_{Well\ 2} = C_{Blend} * V_{Blend} = C_{Blend} * (V_{Well\ 1} + V_{Well\ 2})$

$$\Longrightarrow C_{Blend} = \frac{C_{Well\ 1} * V_{Well\ 1} + C_{Well\ 2} * V_{Well\ 2}}{V_{Well\ 1} + V_{Well\ 2}} = \frac{0.5 * 600 + 12.5 * 350}{600 + 350} = \boxed{4.9\ \text{mg/l}}$$

3. Solution:



$C_1 * V_1 = C_2 * V_2$

$$V_1 = \frac{0.6 * 150}{8} = \boxed{11.25\ \text{gallons liquid polymer}}$$

4. Solution:

$C_1 * V_1 + C_2 * V_2 + = C_3 * V_3 = C_3 * (V_1 + V_2)$

$C_{Line\ 1\ TDS} * V_{Line\ 1} + C_{Line\ 2\ TDS} * V_{line\ 2} = C_{Blend\ TDS} * V_{Blend} = C_{Blend\ TDS} * (V_{Line\ 1} + V_{Line\ 2})$

$$\Longrightarrow C_{Blend\ TDS} = \frac{C_{Line\ 1\ TDS} * V_{Line\ 1\ TDS} + C_{Line\ 2\ TDS} * V_{Line\ 2}}{V_{Line\ 1} + V_{Line\ 2}}$$

$$\Longrightarrow \frac{1500 * \left(\frac{500\ gal}{min} * \frac{MG}{1,000,000\ gal} * \frac{1440 min}{day}\right) + 6 * 250}{\left(\frac{500\ gal}{min} * \frac{MG}{1,000,000\ gal} * \frac{1440 min}{day}\right) + 6} = \boxed{384\ \text{mg/l}}$$

Practice Problems - Sedimentation

1. A circular clarifier has a diameter of 80 ft. If the flow to the clarifier is 1800 gpm, what is the surface overflow rate in gpm/ft

2. A sedimentation basin 70 ft by 25 ft receives a flow of 1000 gpm. What is the surface overflow rate in gpm/ft2?

3. A circular clarifier receives a flow of 3.55 MGD. If the diameter of the weir is 90 ft, what is the weir loading rate in gpm/ft?

Solution

1. $$\text{Surface overflow rate} = \frac{\text{Flow, gpm}}{\text{Clarifier surface area, ft}^2} = \frac{1,800\ \text{gpm}}{(0.785 * 80^2)\text{ft}^2} = \boxed{0.36\ \text{gpm/ft}^2}$$

2. $$\text{Surface overflow rate} = \frac{\text{Flow, gpm}}{\text{Clarifier surface area, ft}^2} = \frac{1,000\ \text{gpm}}{(70\text{ft} * 25\text{ft})\text{ft}^2} = \boxed{0.6\ \text{gpm/ft}^2}$$

3. $$\text{Weir overflow rate} = \frac{\text{Flow, gpm}}{\text{Weir length } ft}$$

$$\Longrightarrow \frac{\frac{3.55\ \text{MG}}{\text{day}} * \frac{1,000,000\ \text{gal}}{\text{MG}} * \frac{\text{day}}{1440\ \text{min}}}{(3.14*90)\ \text{ft}} = \boxed{2,465\ \text{gpm/ft}}$$

Note: The concentration and volume (or flow) units need to be the same. Thus, the gpm flow rate of Line 1 was converted to math the MGD flow rate unit of Line 2.

Practice Problems - Filtration

1. At an average flow of 4,000 gpm, how long of a filter run in hours would be required to produce 25 MG of filtered water?
2. A filter is 40ft long by 20ft wide. During a test of flow rate, the influent valve to the filter is closed for 6 minutes. The water level drop during this period is 16 inches. What is the filtration rate for the filter in gpm/ft^2 ?
3. A water plant has three filters. Each filter is 12 feet wide by 12 feet long. Find the hydraulic loading rate in gpm/sf when all three filters are on-line and the raw water enters the plant at 9.5 mgd.
4. A sand filter will be backwashed at a rate of 8gpm/sf. If the filter is 10 feet wide by 15 feet long, what will the filter backwash rise rate be in inches per minute?
5. A series of filters must be backwashed. Each filter is 20 feet square. If the goal is to achieve a filter backwash rise rate of 30 inches per minute, what should the backwash rate be in gpm/sf?
6. A water plant has 3 filters. The plant is currently treating 5mgd. If each filter is 12 feet wide by 20 feet long, what is the minimum number of filters that should be placed into service to keep the hydraulic loading rate below 20 gpm/sf?
7. Find the yield for a filter in lbs/hr/sf given the following information: Filter operates for 12 hours of each day and captures 95% of the influent solids. The solids load to the filter is 200 pounds per day. The filter is 40 feet square.
8. Coagulated raw water contains 120mg/L of total suspended solids. The water plant produces 2.0mgd and has two sand filters that are 20 feet wide by 20 feet long. If the filters operate 22 hours of each day and capture 99% of the coagulated solids, what is the filter yield in lbs/hr/sf? What is the filter yield total in pounds per day?
9. A series of filters discharge into a combined effluent trough. The trough is 5 feet wide by 80 feet long. A weir runs the full length of the trough. If the water plant capacity is 2 mgd, what is the weir overflow rate in gpd/sf?

Solution

1. $$Flow\ \ rate\ \ (gpm) = \frac{Total\ \ flow\ \ (gal)}{Filter\ \ run\ \ time\ \ (min)}$$

   $$\Longrightarrow Filter\ \ run\ \ time\ \ (min) = \frac{Total\ \ flow\ \ (gal)}{Flow\ \ rate\ \ (gpm)}$$

   $$\Longrightarrow Filter\ \ run\ \ time\ \ (hr) = 25\ \ MG * \frac{1,000,000\ \cancel{gal}}{MG} * \frac{\cancel{min}}{4,000\ \cancel{gal}} * 60\ \frac{hr}{\cancel{min}} = \boxed{104\ \ hrs}$$

2. The volume of the water dropped after the inlet valve was closed would be the filter flow rate. Since the dimensions to calculate are in feet and inches, the volume needs to be converted from ft^3 to gallons

   $$\text{Filtration rate, gpm/ft}^2 = \frac{(40\text{ft}*20\text{ft}*16\cancel{in}*\frac{ft}{12\ \cancel{in}})\cancel{ft^3}*7.48\ \frac{gal}{\cancel{ft^3}}}{40\ \ ft*20\ \ feet} = \boxed{1.7\ \ gpm/ft^2}$$