BASIC MATH HANDBOOK

For Class I & II Water Operators

2015

BASIC MATH HANDBOOK
Overview

This handbook is designed for operators taking the Class I or Class II water operator certification exam. This tool, in addition, to the Class I or Class II Course Manual, along with your operating experience and common sense, should help you pass the certification exam.

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PREFACE

The sections of this handbook are graduated to different levels of math proficiency. Depending on your level of proficiency you may be able to bypass the first two or three sections, which review many of the basic math concepts.

The following is a brief summary of the different chapters of this book.

1. The first part contains a formula sheet of commonly referred to formulas in the water industry.

2. The next part reviews the basic math functions such as addition, subtraction, multiplication and division. The concepts of fractions and decimals, ratios and proportions, percentages and analyzing units are reviewed in the latter part of section.

3. The next section is comprised of conversions and formulas commonly used in the water industry.

4. The next section covers basic geometry, which is essential for calculation of the areas and volumes of water industry treatment and distribution structures.

5. The next section covers the concepts of velocity and flow rates that are commonly used in the water industry.

6. The last section has been dedicated to demonstration examples of water treatment and distribution problems typically encountered by small water systems. These are also the types of example problems encountered on water operator certification exams.

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WATER OPERATOR EXAM FORMULA SHEET

9/1/15

1 minute (min) = 60 seconds (sec)
1 hour (hr) = 60 min
1 day = 24 hr = 1,440 min = 86,400 sec
1 inch (in) = 2.54 centimeters (cm)
1 ft = 12 in
1 ft = 0.433 pounds per square inch (psi)
1 psi = 2.31 ft
1 cubic foot (ft^3) = 7.48 gallons (gal) = 62.38 pounds (lbs)
1 ft^3 = 62.38 lbs
1 cubic yard = 27 ft^3
1 gal = 8 pints
1 gal = 8.34 lbs
1 gal = 3.785 liters (L)
1 lb = 454 grams (g)
1 L = 1,000 milliliters (mL)
1 milligrams per liter (mg/L) = 1 part per million (ppm)
1 % = 10,000 ppm
1 cubic foot per second (cfs or ft^3/sec) = 448 gallons per minute (gpm)
1 gpm = 1,440 gallons per day (gpd)
1 gpd = 2.63 mL/min
1 million gallons per day (MGD) = 694.4 gpm
1 grain per gallon (gpg) = 17.12 mg/L
1 ac-ft = 43,560 ft^3
π (pi) = 3.14
specific gravity (Sp Gr) of water = 1.00

ABBREVIATIONS

V = volume	A = area
v = velocity	D = diameter
Q = flow	r = radius
ft^2 = square feet	C = circumference
W/W = weight/weight	W/V = weight/volume
DT = detention time	HP = horsepower

TEMPERATURE

Fahrenheit (°F) = (1.8 x °C) + 32
Celsius (°C) = (°F - 32) x 0.56

CIRCUMFERENCE, AREA & VOLUME

Circumference (C, ft) = π x D (ft)

Area of a rectangle (A, ft^2) = length (ft) x width (ft)
Area of a circle (A, ft^2) = 0.785 x D $(ft)^2$
Area of a circle (A, ft^2) = π x r $(ft)^2$

Volume of a rectangle (V, ft^3) = length (ft) x width (ft) x height (ft)
Volume of a rectangle (V, gal) = length (ft) x width (ft) x height (ft) x 7.48 (gal/ft^3)

Volume of a cylinder (V, ft^3) = 0.785 x D $(ft)^2$ x height (ft)
Volume of a cylinder (V, gal) = 0.785 x D $(ft)^2$ x height (ft) x 7.48 (gal/ft^3)

DETENTION TIME
Detention time (DT, min) = volume (V, gal) ÷ flow (Q, gpm)

CHLORINATION
Chlorine dose (mg/L) = chlorine demand (mg/L) + chlorine residual (mg/L)

Total chlorine residual (mg/L) = free chlorine residual (mg/L) + combined chlorine residual (mg/L)

POUNDS, DOSAGE & FLOW
Dose (mg/L) = feed (lbs/day) ÷ flow (MGD) ÷ 8.34 (lbs/gal)

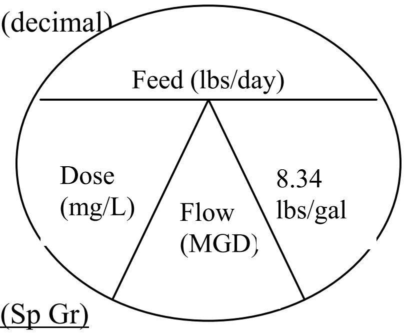
Feed (lbs/day) = dose (mg/L) x flow (MGD) x 8.34 (lbs/gal)

Feed (lbs/day) = dose (mg/L) x flow (MGD) x 8.34 (lbs/gal) ÷ % purity (decimal)

Flow (Q, gpm) = volume (V, gal) ÷ time (min)

Flow (Q, gps) = velocity (v, fps) x area (A, ft^2) x 7.48 (gal/ft^3)

Flow (Q, cfs) = velocity (v, fps) x area (A, ft^2)



COAGULATION AND FLOCCULATION

$$\text{Polymer (lbs)} = \frac{\text{polymer solution (gal)} \times 8.34\ \text{(lbs/gal)} \times \text{polymer (\%)} \times \text{(Sp Gr)}}{100\%}$$

FILTRATION

$$\text{Filtration or backwash rate (gpm/ft}^2\text{)} = \frac{\text{flow (Q, gpm)}}{\text{surface area (ft}^2\text{)}}$$

Unit Filter Rate Volume (UFRV) (g/ft^2) = filtration rate (gpm/ft^2) x filter run (hr) x 60 (min/hr)

Backwash water (gal) = backwash flow (gpm) x backwash time (min)

$$\text{Backwash (\%)} = \frac{\text{backwash water (gal)} \times (100\%)}{\text{water filtered (gal)}}$$

FLUORIDATION

$$\text{Fluoride feed rate (lbs/day)} = \frac{\text{dose (mg/L)} \times \text{flow (MGD)} \times 8.34\ \text{(lbs/gal)}}{\text{Available Fluoride Ion (AFI)} \times \text{chemical purity (decimal)}}$$

$$\text{Fluoride feed rate (gpd)} = \frac{\text{dose (mg/L)} \times \text{flow (gpd)}}{18{,}000\ \text{mg/L}}$$

$$\text{Dose (mg/L)} = \frac{\text{fluoride feed rate (lbs/day)} \times \text{AFI} \times \text{chemical purity (decimal)}}{\text{flow (MGD)} \times 8.34\ \text{(lbs/gal)}}$$

$$\text{Dose (mg/L)} = \frac{\text{solution fed (gal)} \times 18{,}000\ \text{mg/L}}{\text{flow (gpd)}}$$

Chemical	Formula	Available Fluoride Ion (AFI) Concentration	Chemical Purity
Sodium fluoride	NaF	0.453	98%
Sodium fluorosilicate	Na_2SiF_6	0.607	98%
Fluorosilicic acid	H_2SiF_6	0.792	23%

CHEMICAL DOSES

$$\text{Chemical feed setting (mL/min)} = \frac{\text{flow (MGD) x alum dose (mg/L) x 3.785 (L/gal) x 1,000,000 (gal/MG)}}{\text{liquid alum (mg/mL) x 24 (hr/day) x 60 (min/hr)}}$$

$$\text{Dry chemical feeder (lbs/day)} = \frac{\text{chemical applied (lbs)}}{\text{length of application (day)}}$$

$$\text{Solution chemical feeder (lbs/day)} = \frac{\text{chem conc. (mg/L) x V pumped (mL) x 1,440 (min/day)}}{\text{time pumped (min) x 1,000 (mL/L) x 1,000 (mg/g) x 454 (g/lb)}}$$

$$\text{Average feed rate (lbs/day)} = \frac{\text{average feed rate (g/min) x 1,440 (min/day)}}{\text{454 (g/lb)}}$$

DISINFECTION

$$\text{Hypochlorite flow (gpd)} = \frac{\text{container area (ft}^2\text{) x drop (ft) x 7.48 (gal/ft}^3\text{) x 24 (hr/day)}}{\text{time (hr)}}$$

$$\text{Feed rate (gpd)} = \frac{\text{feed rate (lbs /day) x feed dose (mg/L)}}{\text{feed solution (mg/L)}}$$

$$\text{Feed rate (lbs/day)} = \frac{\text{feeder setting (lbs/day)}}{\text{24 (hr/day)}}$$

$$\text{CT (mg/L-min)} = \frac{\text{V (gal) x (}T_{10}\text{) x free chlorine residual (mg/L)}}{\text{flow (gpm)}}$$

$$\text{Free chlorine residual (mg/L)} = \frac{\text{CT (mg/L-min)}}{T_{10}\text{ (min)}}$$

HORSEPOWER

$$\text{Q (gpm)} = \frac{\text{3,956 (HP)}}{\text{head (ft) x Sp Gr}}$$

$$\text{HP} = \frac{\text{voltage x current x efficiency}}{746}$$

$$\text{Water (HP)} = \frac{\text{flow (gpm) x lift (ft) x 8.34 (lbs/gal)}}{\text{33,000 ft-lb/min-HP}}$$

Power (kW-hr/day) = motor (HP) x 24 (hr/day) x 0.746 (kW/HP)

MISC

Percent (%) = part ÷ whole x 100
Part = whole x percent ÷ 100

$$\text{Average} = \frac{\text{sum of measurements}}{\text{number of measurements}}$$

General ratio $\frac{A1}{A2} = \frac{B1}{B2}$

Turnover or drawdown (ft) = pumping (ft) – static (ft)

Potassium permanganate dose (mg/L) = (Iron concentration mg/L) + 2(Manganese concentration mg/L)

$$\text{Alkalinity} = \frac{\text{mL of } H_2SO_4 \text{ x 1,000}}{\text{mL of sample}}$$

$$\text{Hardness} = \frac{\text{mL of EDTA x 1,000}}{\text{mL of sample}}$$

Reservoir Volume (V, gal) = V (ac-ft) x 43,560 (ft^3/ac-ft) x 7.48 (gal/ft^3)

$$\text{Feeder setting, \%} = \frac{\text{desired rate x 100\%}}{\text{maximum rate}}$$

Weight of substance (lbs/gal) = Sp Gr x 8.34 (lbs/gal)

$$\text{Volume needed, } \mu\text{L} = \frac{\text{dose (mg/L) x jar test beaker volume (L)}}{\text{Sp Gr x Conc., \% (expressed as a decimal)}}$$

$$(\text{Volume, mL})_1 = \frac{(\text{concentration, mg/L})_2(\text{volume, mL})_2}{(\text{concentration, mg/L})_1}$$

BASIC MATH

One difficulty in operator certification exams appears to be the solving of math problems. This section is intended to be an aid to the operator in solving everyday operating problems in the operation of a water system. It deals with the basic math that would be required for an operator to accomplish his or her everyday work.

Solving math problems is not any different than solving any type of problem. It requires practice in manipulation and knowledge of what manipulation to make. Given below is an approach to solving math problems

1. Decide what the problem asks.
2. List the information given.
3. Decide what units the answer should have.
4. Perform the calculations necessary to solve the problem.
5. Label the answer and check units.

ADDITION

Adding 10 plus 10 and reaching a conclusion of 20 is a simple operation, but adding complex numbers like 13.333 and 0.0033 pose a larger challenge. Follow these basic rules to avoid arriving at incorrect answers when adding complex numbers:

1. Decimal points and numbers should line up in columns. When this rule is followed correctly, the previous addition problem is easily performed.

Example:

```
  13.3330
+ 00.0033
  13.3363
```

2. Be sure you are not adding apples and oranges. All numbers must represent the same type of units, i.e. inches, pounds, feet. For example, in adding the length of two pieces of pipe, if one is 32 inches and the other is 3 ½ feet, you must convert to common units. First divide 32 inches by 12 to convert to 2.66 feet or multiply 3 ½ feet by 12 to convert to 42 inches before adding the numbers.

Example:

	OR		OR	
32 inches		2.666 feet		$2\ ^{2}/_{3}$ feet
+ 42 inches		+ 3.500 feet		+ $3\ ^{1}/_{2}$ feet
74 inches		6.166 feet		$6\ ^{1}/_{6}$ feet

3. Write down the numbers that you carry over when adding. This will prevent another common error.

Example:

```
   11   y Carry over numbers
  279
+ 165
  444
```

Summary of Addition

- Addition involves the process of summing up numbers.
- The ***order*** by which numbers are added have no impact on the final answer.
- All numbers must be in the same ***units*** (i.e. gpm, feet, inches, etc.)

SUBTRACTION
Subtraction is the reverse operation of addition, but the same general rules apply.

1. Keep all decimal points and numbers aligned in columns.

Example:

$$\begin{array}{r} 4.457 \\ -\ \underline{0.050} \\ 4.407 \end{array}$$

2. Carryover numbers are not used in subtraction, but sometimes 'borrowing' numbers is required. In order to 'borrow' numbers follows these steps:

Example:

$$\begin{array}{r} 374 \\ -\ \underline{286} \\ 88 \end{array}$$

- Step One (the ones column) - Borrow one unit (10) from the 7 in the tens column. You now subtract 6 from 14 to get 8 in the ones column.

- Step Two (column two) – Since you borrowed one unit from the seven, which leaves six, you must now borrow one unit (100) from the one hundreds column. You now subtract 8 from 16 to get 8 in the tens column.

- After borrowing from the one hundreds column you are left with a 2 in that column. Subtracting 2 from 2 is equal to zero. No entry is needed in the thousands column.

- Check your answers. The best way to check you answer in a subtraction problem is to use addition. Add your answer to the number you subtracted and you should get the number you subtracted from:

Example:

$$\begin{array}{r} 374 \\ -\ \underline{286} \\ 88 \end{array} \qquad \textit{Check your answer} \ \times \qquad \begin{array}{r} 88 \\ +\ \underline{286} \\ 374 \end{array}$$

3. Like in addition, be sure you are subtracting apples from apples and not apples from oranges. You must work in like units.

Summary of Subtraction
- Subtraction involves finding a difference.
- The ***order*** by which numbers are subtracted **does** have an impact on the final answer.
- All numbers must be in the same ***units*** (i.e. gpm, feet, inches, etc.)

EXERCISES (Addition/Subtraction):

1. 12 + 54 =
2. 15 + 13 =
3. 23.2 + 12.6 =
4. 25.32 + 23.06 =
5. 4.36 + 102 =
6. 23.5 + 14.32 + 12.444 =
7. 123.45 + 2.3 + 10.1234 =
8. 0.32597 + 2.684 + 18.364 =
9. 0.36 + 0.026 + 0.005 =
10. 1.3 + 0.223 + 1.445 =
11. 72 – 54 =
12. 1.5 – 1.3 =
13. 23 – 12.6 =
14. 2.684 – 18.36 =
15. 6.25 – 9.5 =
16. 67.89 – 10.1 – 3.142 =
17. 6.334 – 0.087 =
18. 8.335 – 3.2589 – 1.3 =
19. 100.23 – 5.34 – 6.789 =
20. 34 – 19.56 – 37.1 =

MULTIPLICATION
There are several rules to remember in multiplication.

1. The number of decimal places in the answer is equal to the sum of decimal places in the numbers multiplied.

Example:

12.002		3 decimal places
X 1.03	+	2 decimal places
36006		
000000		
1200200		
12.36206		5 decimal places

2. Numbers do not have to be apples and apples. They can be apples and oranges. That is why it is important to specify the units that go with the numbers and include them in the answer.

Example: Four men working three hours each would work:

4 men X 3 hours = 12 man-hours of labor

3. The multiplication operation can be indicated by several different symbols. The most common is the multiplication sign (X) or times sign, but it can also be indicated by parentheses {} or by brackets [] or simply with a dot •. The previous example could be indicated several ways, including:

Example:

4 men	X	3 hours	=	12 man-hours
(4 men)		(3 hours)	=	12 man-hours
[4 men]		[3 hours]	=	12 man-hours
4 men	•	3 hours	=	12 man-hours
(4 men)	•	(3 hours)	=	12 man-hours

4. When solving a problem that uses parentheses or brackets, ALWAYS complete the operations inside the parentheses or brackets before performing other operations.

Example: (10-3) (7+2) (3 • 2) = (7) (9) (6) = (7) (9) (6) = 378

Example: [12 –(3+2) (3-1)] [8+(6-2)] = [12 – (5)(2)] [8+4] = [12-10] [12] = [2] [12] = 24

Summary of Multiplication

- The ***order*** by which numbers are multiplied have no impact on the final answer.
- To multiply decimal numbers, the answer must contain the total number of decimal places to the right of the decimal as the sum of the decimal places of the two numbers being multiplied.
- Numbers multiplied by ***unlike*** units must show both units in answer (ex. man-hours, foot-lbs).

DIVISION

Division is the reverse operation of multiplication and the same general rules apply.

1. Division problems can be written several ways. The most common ways are the division sign (÷) and (/). An example could be indicated several ways, including:

Example:

10 men ÷ 2 hours	=	5 man-hours
(10 men)/(2 hours)	=	5 man-hours
$\frac{\text{10 men}}{\text{2 hours}}$	=	5 man-hours

2. When solving a problem that uses parentheses or brackets, ALWAYS complete the operations inside the parentheses or brackets before performing other operations.

Example: (10-3) (7+2) /(3 • 2) =

(7) (9)/ (6) =

63/6 =

10.5

Summary of Division

- The order by which numbers are divided does have an impact on the final answer.
- Again, unlike units (feet vs. inches, days vs. weeks, etc) must be converted to the desired units.
- As shown above, there are different ways of representing the same thing in division.

ORDER OF MATHEMATICAL OPERATIONS
To correctly solve a math equation, the following order must be used:

♦ Parenthesis
♦ Exponential
♦ Multiplication
♦ Division
♦ Addition
♦ Subtraction

A mnemonic is a phrase or device to help us remember something hard by learning something easy. To remember the correct order of math operation, memorize the catchy phrase:

"**P**lease **E**xcuse **M**y **D**ear **A**unt **S**ally".

In addition, math problems should always be worked from the left to the right.

EXERCISES (Multiplication/Division):

1. 15 x 13 =
2. 23.3 x 12.6 =
3. 14.51 x 12.3 =
4. 12.3 x 39.005 =
5. 67.89 x 10.1 =
6. 3.259 x 8.3 =
7. 3.21 x 6.334 =
8. 2.684 x 18.364 x (3 + 2) =
9. (9 + 1) x (4 + 9) =
10. (12 + 2) x 13 =
11. 311 ÷ 12 =
12. 25 ÷ 3 =
13. 250 ÷ 10 =
14. 1 ÷ 3 =
15. 6 ÷ 12 =
16. 0.67 ÷ 0.7 =
17. 12.54 ÷ 1.5 =
18. 25 ÷ (10 + 2) =
19. (25 x 10) ÷ 12 =
20. (25 x 10) ÷ (10 + 2) =

EXERCISES (Addition/Subtraction/Multiplication/Division):

1. The following turbidities were recorded for a week. What was the average daily turbidity?

Day	Turbidity
Monday	8.2
Tuesday	7.9
Wednesday	6.3
Thursday	6.5
Friday	7.4
Saturday	6.2
Sunday	5.9

2. What is the average fluoride concentration based on the following readings?

Reading	Fl^- Conc.
1	0.4
2	0.8
3	0.7
4	1.0
5	0.8
6	1.1
7	1.2

3. The following amounts of alum were used in a treatment plant each month for a year. What was the average monthly requirement of alum?

Month	Pounds of Alum
January	464
February	458
March	455
April	450
May	461
June	465

Month	Pounds of Alum
July	481
August	483
September	476
October	166
November	461
December	463

4. Given the following flow rates, determine the average flow rates for a 24 hour period.

Time	MGD
0:00	1.18
2:00	1.31
4:00	1.25
6:00	1.33
8:00	1.31
10:00	1.22

Time	MGD
12:00	1.13
14:00	1.54
16:00	1.69
18:00	1.75
20:00	1.67
22:00	1.22

FRACTIONS

Fractions are used when you want to express a portion of the whole. If you have a pie that is cut into eight pieces and you eat one, you have eaten 1/8th of the pie (1 divided by 8).

The top number (numerator) represents how many parts you have and the bottom number (denominator) represents the number in the whole.

The bar or slash in the fraction separates the two numbers and can be read as "divided by." This means that the top number (numerator) is divided by the bottom number (denominator). This means that another way to say 1/8 is to say 1 divided by 8.

Fractions can also be used to represent units of measure such as miles per hour or gallons per day where per represents "divided by".

Improper Fractions

Improper fractions have a larger numerator than denominator. Therefore, they represent a number larger than one. Improper fractions can be converted to whole numbers or mixed numbers by performing the division operation indicated by a fraction. Divide the numerator by the denominator.

Example: $\frac{12 \text{ (numerator)}}{8 \text{ (denominator)}} = 12/8 = 1\,{}^{4}/_{8} = 1\,{}^{1}/_{2}$

Reducing Fractions

To reduce a fraction to its lowest terms divide the numerator and denominator by the largest number that equally divides into both of them.

Example: $\frac{10}{30} = \frac{10 \div 10}{30 \div 10} = \frac{1}{3}$

Note: Dividing or multiplying both the numerator and denominator by the same number does not change the value of the fraction. It is the equivalent of dividing or multiplying by 1 (one).

Example: $\frac{10}{10} = 1$

With complex fractions it may not be easy to determine the largest number that equally divides into both the numerator and denominator. In this case, determine a number (factor) that will divide evenly into both. Continue this process until it can no longer be performed by a number larger than one.

Example: $\frac{256 \div 2}{288 \div 2} = \frac{128 \div 2}{144 \div 2} = \frac{64 \div 8}{72 \div 8} = \frac{8}{9}$

Adding and Subtracting Fractions

Before fractions can be added or subtracted the **denominators must be the same**. If the denominators are the same, simply add or subtract the numerators.

Example: $\frac{2}{8} + \frac{3}{8} = \frac{2+3}{8} = \frac{5}{8}$

If the denominators are not the same, they must be manipulated so that they are the same before addition or subtraction can take place. To change denominators so that they are equal, fractions must be multiplied by a fraction representing 1 (one), for example 3/3 or 8/8 or x/x, determined by the desired result.

Example: To add 2/5 and 3/10, fifths must be converted to tenths so that the denominators are the same. Multiply 2/5 by 2/2.

Example: $\frac{2}{5} + \frac{5}{10} = \frac{2\mathbf{(2)}}{5\mathbf{(2)}} + \frac{5}{10} = \frac{4}{10} + \frac{5}{10} = \frac{9}{10}$

In many cases, one denominator can't be changed to match another by multiplication. For example, when adding 1/3 and 1/4, the 1/3 can't be changed to an even fourth. In this case they must both be changed to the **Least Common Denominator (LCD).** The least common denominator is the lowest number that is evenly divisible by both denominators (12 in this case). To convert to the LCD each denominator must be multiplied by a fraction representing 1 (one).

Example: To add 1/3 and 1/4, both must be converted to 12ths.

$$\frac{1(4)}{3(4)} + \frac{1(3)}{4(3)} = \frac{4}{12} + \frac{3}{12} = \frac{7}{12}$$

Multiplying Fractions

To multiply fractions multiply all numerators together to arrive at a new numerator and multiply all denominators together to arrive at a new denominator.

Example: $\frac{1}{4} \text{ x } \frac{3}{7} \text{ x } \frac{5}{3} = \frac{(1)(3)(5)}{(4)(7)(3)} = \frac{15}{84} = \frac{5}{28}$

Dividing Fractions

To divide two fractions, invert the numerator and denominator of the divisor and multiply.

Example: $\frac{1}{3} \div \frac{1}{2} = \frac{1}{3} \text{ x } \frac{2}{1} = \frac{2}{3}$

DECIMALS

Another method of representing a fraction is by using decimals of tenths, hundredths, etc. This is a much better method to use with the use of a calculator. If you have a fraction and want to convert it to a decimal, you should divide the numerator by the denominator.

Decimals are numerical representations of fractions that have 10, 100, 1,000 or some other multiple of 10 as a denominator.

Example:

$\frac{3}{10}$ = 0.3 = three tenths

$\frac{13}{100}$ = 0.13 = thirteen hundredths

Changing a fraction to a decimal

To change a fraction to a decimal, divide the numerator by the denominator.

Example:

$\frac{3}{4} = 3 \div 4 = 0.75$

4 goes into 30 7 times 28

Changing a decimal to a fraction

To change a decimal to a fraction, multiply the decimal by a fraction that represents 1 (one) and has a multiple of 10 in the numerator and denominator, like 10/10, 100/100 etc.

Example:

$$0.0625 \times \frac{10{,}000}{10{,}000} = \frac{625}{10{,}000} = \frac{125}{2{,}000} = \frac{1}{16}$$

PERCENTAGES

Expressing a number in percentage is just another way of writing a fraction or decimal. Think of percentages as parts of 100. In fraction form the denominator of a percentage is always 100.

To change a fraction to percent, multiply by 100.

Example: $\frac{1}{2} \times \frac{100}{1} = \frac{100}{2} = 50\%$

To change a percent to a fraction, multiply by 1/100%

Example: $40\% \times \frac{1}{100\%} = \frac{40\%}{100\%} = \frac{4}{10} = \frac{2}{5}$

Note: the percent signs cancel out.

To change a percentage to a decimal fraction move the decimal point two places to the left.

Example:
28.5% = 0.285
0.1% = 0.001
100% = 1.00

To change a decimal to a percentage move the decimal point two places to the right.

Example:
0.285 = 28.5%
0.001 = 0.1%
1.00 = 100%

EXPONENTS

Indicates how many times a number is to be multiplied by itself.

Example: $2^3 = 2 \times 2 \times 2 = 8$, where 3 is the exponent

$4^2 = 4 \times 4 = 16$, where 2 is the exponent

SQUARE ROOT

Square root is the reverse operation of exponents. Indicates how many times a number is to be divided by itself.

Example: $\sqrt{4} = \sqrt{(2 \text{ X } 2)} = 2$

$\sqrt{81} = \sqrt{(9 \text{ X } 9)} = 9$

ROUNDING OF NUMBER

Rounding is the process of taking a number and reducing the number to one with less digits. If you have a number from your calculation such as 2.346567 and you wanted to round to two significant digits you would look at the third digit to the right of the decimal. If this number is greater than 5, then raise the second digit up one. If the number is less than 5, then leave the number as it is. (The answer to the above number would be 2.35 if rounded to two significant digits).

EXERCISES (Fractions/Decimals/Percentages/Exponents):

1. 3/8 + 1/8 =

2. 1/2 + 3/8 =

3. 2/3 + 1/5 =

4. 3/8 – 1/8 =

5. 1/2 – 3/8 =

6. 2/3 – 1/5 =

7. 3/8 x 1/8 =

8. 1/2 x 3/8 =

9. 2/3 x 1/5 =

10. 3/8 ÷ 1/8 =

11. 1/2 ÷ 3/8 =

12. 2/3 ÷ 1/5 =

13. 3/8 =

14. 1/8 =

15. 1/2 =

16. 1/5 =

17. 2^2 =

18. 3^3 =

19. 5^4 =

20. D^2 =

21. $\sqrt{9}$ =

22. $\sqrt{D^2}$ =

RATIOS AND PROPORTIONS

A ratio is the comparison of two numbers of like units. For example, 1 foot compared to 4 feet 1/4 feet) or 3 pipe length compared to 7 pipe lengths (3/7 pipe lengths).

A proportion is made of two equivalent rations. For example, 4/8 is equal to 1/2.

To solve proportions when one number is unknown, use cross multiplication. Multiply the numerator of one ratio by the denominator of the other ration. This sum should be equal to the number derived by multiplying the denominator of the first ratio by the numerator of the second ratio.

Example:

$$\frac{A}{B} \times \frac{C}{D} \qquad \text{A times D = B times C}$$

When one ratio is known and either the numerator or denominator of a second ratio is known, this cross multiplication technique can be used to find the unknown number.

Example:

$$\frac{X}{6} = \frac{1}{3}$$

$$(X)(3) = (6)(1)$$

$$X = \frac{6}{3}$$

$$X = 2$$

In a proportion, there are two cross products and these cross products are always equal. Proportions come in handy in numerous water calculations.

Example:

If 2 lbs of salt are added to 11 gallons of water to make a solution of a specified strength, how many pounds of salt must be added to 121 gallons to make a solution of the same concentration?

$$\frac{2\text{ lbs}}{11\text{ gal}} = \frac{X}{121\text{ gal}}$$

$$(X)(11\text{ gal}) = (2\text{ lbs})(121\text{gal})$$

$$X = \frac{(2\text{lbs})(121\ \cancel{\text{gal}})}{11\ \cancel{\text{gal}}} = \frac{242\text{ lbs}}{11} = 22\text{ lbs}$$

Note: gallons cancel each other out

Therefore, 22 lbs of salt must be added to 121 gallons of water to reach the same concentration as when 2 lbs of salt is added to 11 gallons.

EXERCISES (Proportions):

1) $\frac{X}{7} = \frac{36}{28}$ 2) $\frac{X}{14} = \frac{4}{7}$ 3) $\frac{X}{30} = \frac{1}{6}$

4) $\frac{X}{42} = \frac{3}{7}$ 5) $\frac{X}{27} = \frac{10}{18}$ 6) $\frac{X}{48} = \frac{13}{26}$

7) $\frac{X}{33} = \frac{32}{24}$ 8) $\frac{X}{16} = \frac{13}{26}$ 9) $\frac{X}{8} = \frac{18}{81}$

10) $\frac{X}{8} = \frac{108}{72}$ 11) $\frac{X}{84} = \frac{4}{7}$ 12) $\frac{X}{70} = \frac{16}{14}$

13) $\frac{X}{2} = \frac{2}{5}$ 14) $\frac{X}{4} = \frac{5}{10}$ 15) $\frac{X}{14} = \frac{27}{21}$

16) If 18 gallons of permanganate weighs 54 pounds, then 27 gallons weigh how many pounds?

17) Gary can read three meters in 18 minutes. How many meters can he read in 33 minutes?

18) Two gallons of bleach cost $3.80. Five gallons of bleach costs?

19) If an operators makes $15.00 per hour, how much will he make in 3.5 hours?

20) If a water plant uses 2.6 gallons of Delpac per hour, how much will be used in 8 hours?

THE METRIC SYSTEM

The **metric system** is a system of units and measurements based on multiples of 10. The metric system is use widely throughout most of the world but used infrequently in the US. The metric system is also referred to as the International System of Units (SI).

Most calculations performed by water system operators are in the English or US system of measurements (i.e. inches, feet, miles, pounds, gallons, etc.). Metric units, however, are commonly used in the laboratory and often for calculating chemical dosages and identifying contaminant concentrations.

Common units of length measurement in the metric system are the millimeter (mm), the centimeter (cm), the decimeter (dm), the meter (m) and the kilometer (km). The relationships among these length measurements are shown below.

- 1 centimeter = 10 millimeters
- 1 decimeter = 10 centimeters
- 1 meter = 100 centimeters
- 1 kilometer = 1,000 meters

Common units of volume measurement in the metric system are the milliliter (mL), the cubic centimeter (cc), the liter (L) and the cubic meter. The relationships among these volume measurements are shown below.

- 1 milliliter = 1 cubic centimeter
- 1 liter = 1,000 milliliters
- 1 cubic meter = 1,000 liters

Common units of mass measurement in the metric system are the microgram (µg), the milligram (mg), the gram (g) and the kilogram (kg). The relationships among these mass measurements are shown below.

- 1 milligram = 1,000 micrograms
- 1 gram = 1,000 milligrams
- 1 kilogram = 1,000 grams

The metric system also has the following special relationships.

- 1 milliliter of water weighs 1 gram and has a volume of 1 cubic centimeter at a temperature of 4° C.
- 1 liter of water weighs 1 kilogram and has a volume of 1 cubic decimeter at a temperature of 4° C.

UNIT CONVERSIONS

In his section you will learn a method of converting from one unit to another, such as cubic feet to gallons. This is one of the most difficult tasks for the operator. You must **always** write the units down with each number. All units must be checked prior to your calculations to make sure your answer will be in correct units. If the units are incorrect the number that you calculate is incorrect as well.

By analyzing units (called dimensional analysis) in a formula or mathematical calculation you can determine if the problem is set up correctly. To check a math setup, work only with the units of measure and not with the numbers. To analyze math setups you need to know three things.

1. How to convert a horizontal fraction to vertical.

Example: cu ft/min = $\frac{\text{cu ft}}{\text{min}}$

2. How to divide by a fraction.

Example: gal/min ÷ gal/cu ft = $\frac{\text{gal}}{\text{min}} \times \frac{\text{cu ft}}{\text{gal}}$

3. How to cancel terms.

Example: $\frac{\cancel{\text{gal}}}{\text{min}} \times \frac{\text{cu ft}}{\cancel{\text{gal}}} = \frac{\text{cu ft}}{\text{min}}$

Example: 100 cubic feet is _?_ gallons = $\cancel{\text{100 cubic feet}} \times \frac{\text{7.48 gallons}}{\cancel{\text{1 cubic foot}}}$ = 750 gallons

750 gallons is _?_ cubic feet = $\cancel{\text{750 gallons}} \times \frac{\text{1 cubic foot}}{\cancel{\text{7.48 gallons}}}$ = 100 cubic feet

Note: Use the formula sheet to find how many gallons are in a cubic foot.

EXERCISES (Unit Conversions):

Convert the following:

1. 87 seconds to minutes:
2. 1045 seconds to minutes:
3. 24 minutes to seconds:
4. 15 minutes to seconds:
5. 109 minutes to hours
6. 44 minutes to hours
7. 2.8 hours to minutes
8. 0.5 hours to minutes
9. 13 hours to days
10. 45 hours to days
11. 0.5 days to hours
12. 3 days to hours
13. 2 days to min
14. 452 min to days
15. 250 gpm to MGD
16. 600 gpm to MGD
17. 120 gpm to MGD
18. 0.25 MGD to gpm
19. 1.3 MGD to gpm
20. 0.12 MGD to gpm

EXERCISES (Unit Conversions): (continued)

Convert the following:

21. 1500 cuft to gal

22. 5 cuft to gal

23. 500 cuft to gal

24. 100 gal to cuft

25. 2500 gal to cuft

26. 45 gal to cuft

27. 2.5 gal to lbs

28. 20 gal to lbs

29. 110 gal to lbs

30. 24 lbs to gal

31. 53 lbs to gal

32. 150 lbs to gal

33. 20 psi to ft

34. 100 psi to ft

35. 75 psi to ft

36. 100 ft to psi

37. 50 ft to psi

38. 500 ft to psi

39. 90 cuft to lbs

40. 150 lbs to cuft

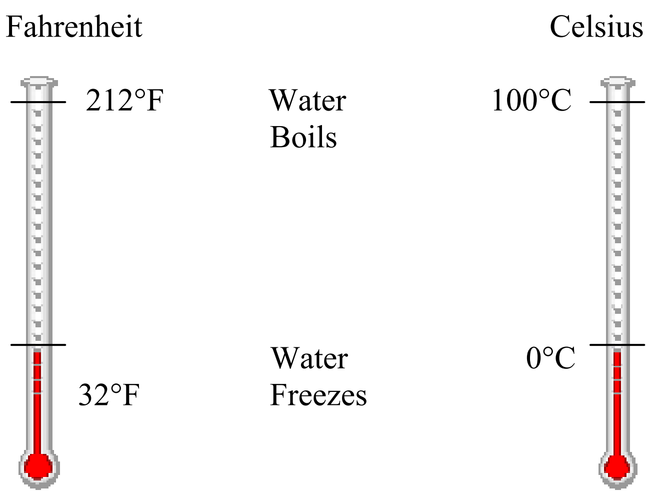
TEMPERATURE

There are two common scales for temperature, Fahrenheit (°F) and Celsius (°C) (centigrade).

Note: The following equations are found on your formula sheet:

Fahrenheit = (1.8 x °C) + 32°

Celsius = 0.56 x (°F - 32°)



Example: Convert 41°F to Celsius

°C = 0.56° x (°F - 32°) =
0.56° x (41° – 32°) =
0.56° x 9° =
5.04°C

Example: Convert 10°C to Fahrenheit

°F = (1.8 x °C) + 32° =
(1.8 x 10°C) + 32° =
18° + 32° =
50°F

EXERCISES (Temperature):

Convert the following temperatures from Fahrenheit to Celsius.

1. 32°F
2. 70°F
3. 50°F
4. 85°F
5. 43.7°F

Convert the following temperatures from Celsius to Fahrenheit.

6. 32°C
7. 0°C
8. 10°C
9. 17°C
10. 23.4°C

REARRANGEMENT OF A FORMULA

This procedure allows a formula to be converted to solve for an unknown;

Example: Detention time = $\frac{\text{Volume}}{\text{Flow}}$ OR Flow = $\frac{\text{Volume}}{\text{Detention Time}}$

The rules for the rearrangement of a formula are:

1. If the unit that you <u>do not</u> know is being divided by something you know, then multiply both sides of the equation (on each side of the equal sign) by the units that you know. Then cancel (cross out) terms.

Example: (You know everything but the volume)

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Flow X Detention Time} = \frac{\text{Volume}}{\cancel{\text{Flow}}} \text{ X } \cancel{\text{Flow}}$$

Volume = Detention Time x Flow

2. If the unit you do not know is divided into something that you know, then multiply both sides of the equation by the unit you do not know. After that divide both the sides of the equation by the unit that you do know.

Example: (You know everything but the flow)

$$\text{Detention time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Flow X Detention Time} = \frac{\text{Volume}}{\cancel{\text{Flow}}} \text{ X } \cancel{\text{Flow}}$$

$$\frac{\text{Flow X } \cancel{\text{Detention Time}}}{\cancel{\text{Detention Time}}} = \frac{\text{Volume}}{\text{Detention Time}}$$

$$\text{Flow} = \frac{\text{Volume}}{\text{Detention Time}}$$

SOLVING WORD PROBLEMS

1. Read the problem:
    a. Underline the given information (Note: you cannot write on your test paper though).
    b. Circle what is being asked for (Note: you cannot write on your test paper though).
    c. Draw a picture and label with the given information (on scrap paper).

2. Stop and think about what is being asked for:
    a. Look at the units; many times the units of the item being asked for will tell you how to do the problem.
    b. Do not go on until you understand what is being asked and you know how to proceed.

3. Select the proper formula:
    a. Write down the formula and then start writing down the various information that has been given to you. If you do not have enough information to fill in all but one unit in the formula, you have the wrong formula for the problem.

4. Solve the formula.

5. Ask if the answer is reasonable:
    a. If it is not, you should go back and check your work or possibly you are not using the correct formula.

LINEAR MEASUREMENT

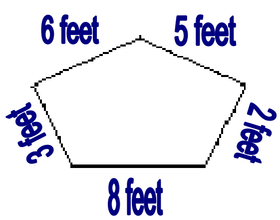
Linear measurements determine the length or distance along a line or curve, and are generally expressed in English units (inches, feet, yards, and miles) or metric units (centimeters, meters, and kilometers). These measurements of distance are used to determine lengths, perimeters of shapes, diameters of circles, and circumferences of circles.

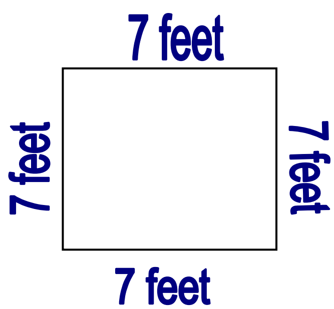
Perimeters

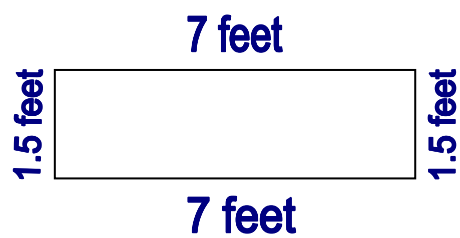
Perimeters of shapes that are made up of straight lines are determined by adding the length of each side. It can be found using the formula: Perimeter = $length^1 + length^2 + length^3$ etc…

Perimeter calculations can be used to determine how many linear feet of pipe will be necessary for a specific design or how much wire will be needed to fence off an area.

Example:





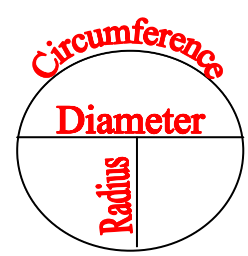


Perimeter= 3+8+2+6+5 = 24 feet	Perimeter = 7+7+7+7 = 28 feet	Perimeter = 1.5+7+7+1.5 = 17 feet

Circles

There are three main linear measurements of circles: circumference, diameter, and radius. These measurements are necessary for determining areas of circles and volumes of cylinders and spheres.

The **diameter** of a circle is the length of a straight line that crosses the center of the circle from one edge of the circle to another. It is twice the length of the radius. It can be determined by the formula:
$D = 2r$ *where: D = Diameter and r = radius*

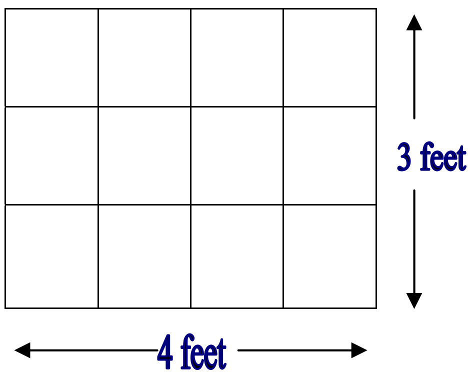


The **radius** of a circle is the distance from the center of the circle to the edge of the circle. It can be determined by the formula: $r = \frac{D}{2}$ *where: r = radius and D = Diameter*

The **circumference** of a circle is the distance around the circle and is always equal to 3.14 times the length of the diameter. The special relationship between the diameter and circumference generates a constant number named pi (pronounced pie) and is designated by the Greek symbol (π), where π = 3.14. If you know the diameter of a circle you can always calculate the circumference using the formula: $C = \pi D$ *where: C = Circumference, D = Diameter and* $\pi = 3.14$.

AREA
The Area of any figure is measured in the second dimension or in square units. In the English system that we normally use in the United States, this would be square inches, square feet, etc. The most common mistake made by operators in working with math is that they do not convert the units so that they are the same. An example of this would be trying to use inches and feet in the same problem, without converting one unit or the other.

Rectangle
The area of any rectangle is equal to the product of the length multiplied by the width of the figure. Formula: Rectangle Area = (length)(width) = *lw*



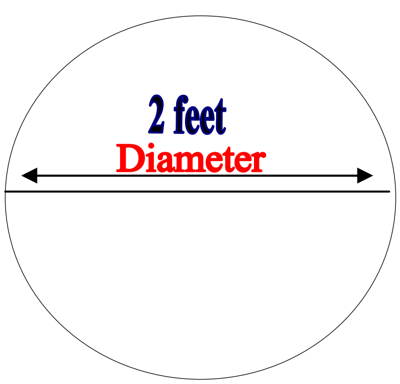
Area of rectangle A = (length)(width)
= (4 feet)(3feet)
= 12 square feet

Example: Find the area of a rectangle that has a length of 5 feet and width of 3.6 feet?

A = *l* X *w*
= 5 ft. X 3.6 ft.
= 18 ft^2

Circle
The area of a circle is found in a different manner in that a circle does not have length and width measurements. A circle is defined as a figure that has an arc that is equidistant in all areas from a center point. A line drawn from the center point to any point on the arc is called the radius. A straight line drawn through the center from arc to arc is called the diameter of the circle.

The area of a circle is found by squaring the diameter. By doing this operation the units will become squared and at that point the units are right for finding area. When you work an area problem you multiply the square of the diameter times 0.785. The formula for the area of a circle can be written as: Circle Area = $(0.785)(D^2)$.



Area of circle A = $(0.785)(D)^2$
= $(0.785)(2\text{ ft})^2$
= $(0.785)(4\text{ ft}^2)$
= 3.14 ft^2

Example: What is the area in square feet of a circular tank that has a diameter of 35 feet?

Area $= (0.785) \text{ X } (35\text{ft})^2$
$= (0.785) \text{ X } (1225 \text{ sq. ft.})$
$= 961.63$ sq. ft.

SURFACE AREA

With the formulas that we have used to this point it would be a simple matter to find the number of square feet in a room that was to be painted. The area of all of the walls would be calculated and then added together. This would include the ceiling as well as all of the walls in the room.

Example: What is the surface area of a tank that has a diameter of 60 feet and a height of 20 feet?

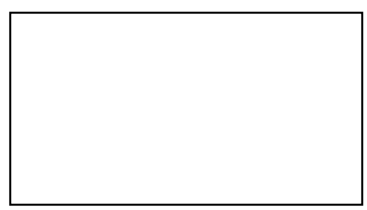
The area of the top and bottom ends are equal to:

Area $= 0.785 \text{ X } (D)^2 \text{ X } 2$
$= 0.785 \text{ X } (60\text{ft})^2 \text{ X } 2$
$= 0.785 \text{ X } 3600 \text{ ft}^2 \text{ X } 2$
$= 2826 \text{ ft}^2 \text{ X } 2$
$= 5652 \text{ ft}^2$

Note: You would multiply by 2, because there are two sides to account for.

The area of the side wall is equal to the circumference of the tank times the depth. When you find the circumference it is as though you cut the tank depth and unroll the side to make it a rectangular figure.

A $= \pi$ X diameter X height
$= 3.14 \text{ X } 60 \text{ ft X } 20 \text{ ft}$
$= 188.4 \text{ ft X } 20 \text{ ft}$
$= 3768 \text{ ft}^2$



The total surface area of the cylinder is equal to the sum of the two areas or

Surface Area $= 5652 \text{ ft}^2 + 3768 \text{ ft}^2 = 9420 \text{ ft}^2$

VOLUME

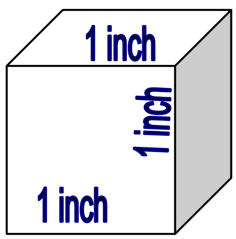
Water operators are usually more interested in how many gallons a tank will hold, etc. Volume is measured in the third dimension where a depth or height of the figure is known. The units used are generally cubic feet, cubic inches or gallons. (In the water field the volume of most tanks are measured in gallons).

Volume is found by taking the area of the base of the figure and multiplying times the height of the figure. All figures that have been discussed to this point can have a volume calculated for them if you know the depth or height of the figure. Therefore, Volume measurements are closely related to area.

Formula: Volume = (Surface Area)(Depth)

Rectangle

The volume of a tank that has a rectangular shape is found by multiplying the length times the width times the depth of the tank. This will give you the answer in cubic feet.



1 cubic inch

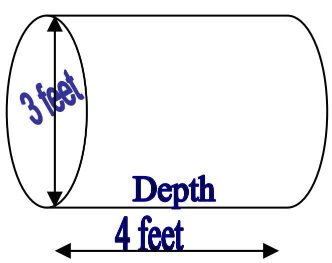
Volume of Rectangle
V = (Area)(Depth)
V = (length)(width)(depth)
V = (1 in)(1 in)(1in)
V = 1 in^3

Example: What is the volume in cubic feet of a tank that is 50 ft long, 30 ft wide and 12 ft deep?

Volume = *l* X *w* X *h*
= 50 ft X 30 ft X l2 ft
= 1500 ft^2 X 12 ft
= 18,000 ft^3

Cylinder

The volume of a cylinder is equal to the area of the base times the height of the figure.



Volume of Cylinder
V = (Area)(Depth)
V = 0.785 X (D^2) X (Depth)
V = 0.785 X (4 ft)^2 X (3ft)
V = 37.68 ft^3

Example: Find the volume of a cylinder with a diameter of 10 feet and a depth of 10 feet?

Volume = 0.785 x (D)^2 x (Depth)
= 0.785 x (10ft)^2 x (10 ft)
= 0.785 x 100ft^2 x l0ft
= 785ft^3

EXERCISES (Area/Volume/Circumference/Perimeter):

1. What is the area of a filter that is 8 ft by 12 ft?

2. What is the area of a clearwell that has a width of 25 ft and a length of 80 ft?

3. A tank is 10 ft long, 10 ft wide, with a depth of 5 ft. What is the area of the tank?

4. A tank has a diameter of 100 ft. What is the area?

5. What is the area of a clarifier with a diameter of 30 feet?

6. What is the area of a tank with a radius of 20 ft?

7. A tank is 10 ft long, 10 ft wide, with a depth of 5 ft. What is the volume of the tank?

8. What is the volume of a sedimentation basin that is 12 ft long, 6 ft wide and 10 ft deep?

9. What is the gallon capacity of a tank with the following dimensions, 12 ft by 10 ft by 8 ft?

10. A tank is 25 ft wide, 75 feet long and has a water depth of 10 ft. How many gallons of water are in the tank?

11. A clarifier has a diameter of 50 ft. If the depth of the water is 15 ft, what is the volume?

12. What is the volume of a piece of pipe that is 2000 ft long and has a diameter of 18 inches?

13. A section of 6 inch main is to be filled with chlorinated water for disinfection. If 1320 ft of the pipe is to be disinfected, how many gallons of water will be required?

14. A tank has a diameter of 100 ft. What is the circumference?

15. What is the circumference of a clarifier with a diameter of 30 feet?

16. What is the perimeter of a water plant with the following dimensions: 100 ft, 250 ft, 300 ft, 500 ft, and 220 ft?

17. What is the perimeter of a water plant with the following dimensions: 145 ft, 200 ft, 300 ft, 500 ft, and 240 ft?

18. Your system has just installed 2, 000 feet of 8” line. How many gallons of water will it take to fill this line?

19. Your finished water storage tank is 35’ in diameter and 65’ high. With no water entering it the level dropped 4’ in 5 hours. How many gallons of water were used in this period?

20. If a clarifier has a diameter of 68 feet, and a height of 86 feet, what is the surface area of the water within the clarifier?

VELOCITY

Velocity is the measurement of the speed at which something is moving. It is expressed by the distance traveled in a specific amount of time. Velocity can be expressed in any unit of distance per any unit of time, as in three miles per year, a mile per second, etc. However, for the purpose of measuring water's rate of flow in a channel, pipe, or other conduit, it is usually expressed in feet per second (ft/sec), or feet per minute (ft/min).

Velocity is important to the water operator because if the velocity becomes too fast the friction loss in the pipe becomes very high and costs additional money for energy. If you want to calculate the velocity you need to know the distance traveled and length of time that it took to cover the given distance. The following formula is used to calculate the velocity of a liquid**.**

Formula: $\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$

Example: The water in a pipe travels 210 feet every three minutes. Calculate the velocity of the water.

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$
$$= \frac{210 \text{ ft}}{3 \text{ min}}$$
$$= 70 \text{ ft/min}$$

Example: The water in a pipe travels 1500 feet every hour. What is the velocity of the water in ft/min?

1 hr x (60 min/1 hr) = 60 min *Note: First convert the time into minutes.*

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$
$$= \frac{1500 \text{ ft}}{60 \text{ min}}$$
$$= 25 \text{ ft/min}$$

FLOW

The measurement of flow in the water industry is one of the most important calculations that an operator can make in his or her workday. The management of the flow in the water system dictates the operation of the total system from the feeding of chemicals to the collection of bills**.**

Flow in the treatment plant is a function of the velocity of the water at a given point in the treatment multiplied by the cross sectional area of the pipe or channel. (The cross sectional area is equal to the area of the end of the pipe or channel and if the pipe or channel is not flowing full the area would be calculated using the depth of the water flowing in the pipe).

Flow is generally measured in gallons per minute (gpm), gallons per day (gpd), or million gallons per day (MGD). If you are working with a flow channel or pipe, the cross sectional area multiplied by the velocity will give you the flow in the form of cubic measure per basis of time, such as cubic feet per second.

Formula: Flow = Cross sectional Area X Velocity OR $Q = Av$

Example: Find the flow in ft^3/sec of a 1 ft diameter pipe if the velocity equals 5 ft/sec?

$$Q = Av$$
$$= [0.785 \text{ X } (\text{diameter})^2] \text{ X } (v)$$
$$= [0.785 \text{ X } (1 \text{ ft})^2] \text{ X } (5 \text{ ft/sec})$$
$$= 3.92 \text{ ft}^3\text{/sec}$$

If the flow in a water system is in cubic feet the operator can convert the units into any of the other normal units, such as gallons per minute, gallons per hour or gallons per day. The units of gallons are commonly used by the operators rather than cubic feet. For example, when the flow from a pump is measured in gallons per minute, the units can be converted to gallons per hour by multiplying by 60 minutes per hour. The units of flow in gallons per hour can be converted to gallons per day by multiplying the gallons per hour times 24 hours per day. A more common method of expressing flow in larger treatment plants is million gallons per day. Million gallons per day is computed by dividing gallons per day by one million gallons (1,000,000 gallons).

If the flow has been expressed as cubic feet per second and you want to convert the flow to gallons per minute, you would use the following method.

Example: Find the flow in gpm if the flow in cubic feet per second is equal to 10.

$$10 \text{ cfs X } \frac{448 \text{ gpm}}{1 \text{ cfs}} = 4{,}480 \text{ gpm}$$

Note: Use the formula sheet for conversion.

If the flow has been expressed as cubic feet per second and you want to convert the flow to million gallons per day, you would use the following method.

Examp1e: What is the flow in MGD if it is measured at 500 cfs?

$$500 \text{ cfs X } \frac{1 \text{ MGD}}{1.55 \text{ cfs}} = 323 \text{ MGD}$$

DETENTION TIME

The detention time of a tank or piping system is the time that it would take to fill the system or empty the system. This is a theoretical time in that it will not tell you if the tank is short circuiting or not. The detention time is found by calculating the volume of the vessel and dividing it by the flow to the vessel. The important thing to remember is that the volume and flow must have the same units.

Formula: $\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$ OR $DT = \frac{V}{Q}$

Example: A rectangular basin 12 feet long and 9 feet wide and 6 feet deep. It treats a flow of 90,000 gallons per day. Determine the detention time in hours.

1. Determine tank volume in gallons.

   Volume = (length)(width)(depth)
   = (12 ft)(9 ft)(6 ft)
   = $648\ ft^3$

2. To convert from cubic feet to gallons multiply by 7.48. Your formula sheet shows that there are 7.48 gallons in 1 cubic foot.

   $648\ \cancel{ft^3} \times 7.48\ gal/\cancel{ft^3} = 4{,}847$ gallons

3. Calculate the resulting detention time in hours using the formula stated above.

   $\text{Detention Time} = \frac{(4{,}847\ \cancel{gal})}{90{,}000\ \cancel{gal}/day} = 0.054\ day$

   $\text{Detention Time (hr)} = 0.054\ \cancel{day} \times \frac{24\ hr}{1\ \cancel{day}} = 1.3\ hours$

Example: How many hours would it take to use the water in 120,000 feet of 8 inch pipe with a flow out of the system of 1000 gpm and a flow into the system of 250 gpm?

$8\ \cancel{in} \times (1\ ft/12\ \cancel{in}) = 0.67\ ft$ *Note: First convert inches to feet.*

$$\text{Detention Time} = \frac{\text{Volume}}{(\text{flow out} - \text{flow in})}$$

$$= \frac{(0.785)\ (0.67\ ft)^2\ (120{,}000\ ft)}{(1000\ gpm - 250\ gpm)}$$

$$= \frac{(42{,}286\ \cancel{ft^3})}{750\ \cancel{gal}/min} \times \frac{(7.48\ \cancel{gal})}{1\ \cancel{ft^3}}$$

$$= (422\ \cancel{min}) \times \frac{(1\ hr)}{60\ \cancel{min}}$$

$$= 7.0\ hours$$

CALCULATING FLOW

If you know the tank volume and detention time you can calculate the flow.

Formula: $\text{Flow} = \frac{\text{Volume}}{\text{Detention Time}}$ OR $Q = \frac{V}{DT}$

Example: Determine the required flow in gal/day for a settling basin that is 20 feet long, 10 feet wide, and six feet deep and has a known detention time of 3 hours.

$Q = V / DT$

$Q = \frac{(20\ ft)\ (10\ ft)\ (6\ ft)}{3\ hr}$

$Q = \frac{(1200\ \cancel{ft^3})}{3\ hr} \times \frac{(7.48\ gal)}{1\ \cancel{ft^3}}$

$Q = \frac{(8976\ gal)}{3\ \cancel{hr}} \times \frac{(24\ \cancel{hr})}{1\ day}$

$Q = 71{,}808\ gal/day$

EXERCISES (Velocity/Flow/Detention Time):

1. Find the detention time of a tank that measures 50 feet long, 30 feet wide and 10 feet deep with a flow to the tank of 1500 gpm?

2. The flow to a tank that is 50 ft long, 30 ft wide and 10 ft deep is 0.32 MGD. What is the detention time in hours?

3. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet when the inflow is 1000 gpm?

4. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet, when it starts full and is discharging 2500 gpm and has an inflow of 1500 gpm?

5. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet, when it starts 1/2 full and is discharging 2500 gpm and has an inflow of 1500 gpm?

6. A channel 3 ft wide has water flowing to a depth of 2.5 ft. If the velocity through the channel is 2 fps, what is the cfs flow rate through the channel?

7. The flow through a 6 inch diameter pipeline is moving at a velocity of 300 ft/sec. What is the cfs flow rate through the pipeline?

8. If a pipe has a 1-ft diameter, what is the velocity of the water if the pipe is carrying $2ft^3$/sec?

9. A sedimentation tank holds 80,000 gallons and the flow into the plant is 855 gpm. What is the detention time in minutes?

10. What is the detention time in a sedimentation basin 80 ft long, 20 ft wide and 10 ft high if the rate of flow is 5800 gal/min?

CHEMICAL DOSING

The water operator needs to understand the importance of calculating the amount of chemical that he or she adds to the water of the community. This unit may be expressed as either parts per million (ppm) or milligrams per liter (mg/L). They are for all practical purposes considered to be equal. *1 ppm = 1 mg/L*

The calculation tells the operator the number of pounds of chemical being added to the water per million pounds of water. The loadings are calculated by multiplying the following; the flow expressed in MGD, the weight of one gallon of water (8.34 lbs/gal), the amount of chemical being added in parts per million.

Calculating Dose

To calculate dose, you must rearrange the previous formula for calculating chemical feed.
See formula below.

Formula: $$\text{Dose (mg/L)} = \frac{\text{Chemical Feed (lbs/day)}}{\text{Flow (MGD) X (8.34 lbs/gal)}}$$

Example: A 0.52 MGD system is feeding chlorine at a rate of 12 lbs/day. What will be the resulting chlorine dose?

$$\text{Dose (mg/L)} = \frac{\text{Chemical Feed (lbs/day)}}{\text{Flow (MGD) X (8.34 lbs/gal)}}$$

$$= \frac{\text{12 lbs/day}}{\text{(0.52 MGD)(8.34 lbs/day)}}$$

$$= \text{2.76 mg/L}$$

To calculate the dose when the feed is a percent-solution, you must multiply the dose by the percentage as a decimal.

Example: What is the dose of the previous example if the feed is a 12% available chlorine solution?

Dose (mg/L) @ 12% = (2.76 mg/L)(0.12)
= 0.33 mg/L

Calculating Chemical Feed

Formula: Chemical Feed (lbs/day) = Dose (mg/L) X Flow (MGD) X (8.34 lbs/gal)

Example: How many pounds of chlorine must be added to 1.5 MGD to obtain 1.2 ppm of chlorine residual?

Chemical Feed (lbs/day) = Dose (mg/L) X Flow (MGD) X (8.34 lbs/gal)
= (1.2 ppm) X (1.5 MGD) X (8.34 lbs/gal)
= 15 lbs/day

To calculate the cost of the feed, you must convert the feed into price per time period.

Example: If chlorine costs \$.47/lb, what is the daily cost of chlorinating the water in the previous example?

$$\text{Chemical Feed (\$/day)} = \frac{(15\text{ lbs})}{1\text{ day}} \times \frac{\$0.47}{1\text{ lb}}$$

$$= \$7.05/\text{day}$$

Many chemicals that are used in the operation of a water system are not pure elemental chemical, but contain some other chemical in combination with the one that you are interested in. An example of this would be calcium hypochlorite (HTH), which is 70 percent available chlorine.

Formula: $\text{Chemical Feed (lbs/day)} = \frac{\text{pure chemical (lb/day)}}{\text{\% purity (as a decimal)}}$

Example: How many pounds of HTH would be required to raise the chlorine residual to 50 ppm if a tank contains 0.5 MGD? HTH is 70 percent pure.

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

$$= \frac{(50\text{ ppm})\ (0.5\text{ MGD})\ (8.34\text{ lbs/gal})}{0.70}$$

$$= \frac{208.5\text{ lbs/day}}{0.70}$$

$$= 298\text{ pounds HTH/ day}$$

Calculating Flow
To calculate flow, you also rearrange the chemical feed formula. *See formula below.*

Formula: $\text{Flow (MGD)} = \dfrac{\text{Chemical Feed (lbs/day)}}{\text{Dose (mg/L) X (8.34 lbs/gal)}}$

Example: What would the calculated flow be with a feed rate of 15 pounds per day and a chlorine dose of 1.2 mg/L?

$$\text{Flow (MGD)} = \frac{\text{Chemical Feed (lbs/day)}}{\text{Dose (mg/L) X (8.34 lbs/gal)}}$$

$$= \frac{\text{15 lbs/day}}{\text{(1.2 mg/L)(8.34 lbs/day)}}$$

$$= \text{1.5 MGD}$$

EXERCISES (Chemical Dosing):

1. Determine the chlorinator setting (lbs/day) needed to treat a flow of 3 MGD with a chlorine dose of 4 mg/L.

2. Determine the chlorinator setting (lbs/day) if a flow of 3.8 MGD is to be treated with a chlorine dose of 2.7 mg/L.

3. A jar test indicates that the best dry alum dose is 12 mg/L. If a flow is 3.5 MGD, what is the desired alum feed rate?

4. The chlorine feed rate at a plant is 175 lbs/day. If the flow is 2,450,000 gpd, what is the dosage in mg/L?

5. A total chlorine dosage of 12 mg/L is required to treat a particular water. If a flow 1.2 MGD and the hypochlorite has 65% available chlorine how many lbs/day of hypochlorite will be required?

6. A flow of 800,000 gpd requires a chlorine dose of 9 mg/L. If chlorinated lime (34% available chlorine) is to be used, how many lbs/day of chlorinated lime will be required?

7. Determine the flow when 45 lbs of chlorine results in a chlorine dose of 1.7 mg/L.

8. A pipeline 10 inches in diameter and 900 ft long is to be treated with a chorine dose of 50 mg/L. How many lbs of chlorine will this require?

9. The flow meter reading at 8 am on Wednesday was 18,762,102 gal and at 8 am on Thursday was 19,414,522 gal. If the chlorinator setting is 15 lbs for this 24 hour period, what is the chlorine dosage in mg/L?

10. To disinfect an 8-inch diameter water main 400 feet long, an initial chlorine dose of 400 mg/L is expected to maintain a chlorine residual of over 300 mg/L during a three hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution is needed?

11. A container weighing 55 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 205 grams after 4 minutes. What is the dosage in lbs/day?

CHLORINE DEMAND

The chlorine dosage is equal to the chlorine demand plus the residual.

Formula: Dose (mg/L) = Demand (mg/L) + Residual (mg/L)

Example: What is the chlorine dose, if the chlorine demand is 4.8 mg/L and the chlorine residual is 2 mg/L?

Dose (mg/L) = Demand (mg/L) + Residual (mg/L)
= 4.8 mg/L + 2 mg/L
= 6.8 mg/L

Example: What is the chlorine demand in milligrams per liter if the chlorine dose is 3.2 mg/L and the residual is 0.3 mg/L?

Demand (mg/L) = Dose (mg/L) – Residual (mg/L)
= 3.2 mg/L - 0.3 mg/L
= 2.9 mg/L

Example: What is the chlorine residual, if the chlorine demand is 1.8 mg/L and the chlorine dose is 10 mg/L?

Residual (mg/L) = Dose (mg/L) – Demand (mg/L)
= 10 mg/L – 1.8 mg/L
= 8.2 mg/L

EXERCISES (Chemical Demand):

1. What is the chlorine demand in mg/L, if the chlorine dose is 3.2 mg/L and the chlorine residual is 0.3 mg/L?

2. What is the chlorine residual, if the chlorine demand is 1.8 mg/L and the chlorine dose is 10 mg/L?

3. What is the chlorine dose, if the chlorine demand is 4.8 mg/L and the chlorine residual is 2 mg/L?

4. The chlorine demand is 7 mg/L and the chlorine residual is 0.2 mg/L. What is the chlorine dose?

5. The chlorine dose is 5 mg/L and the chlorine demand is 2.7 mg/L. What is the chlorine residual?

6. The chlorine dose is 12 mg/L and the chlorine residual is 1.5 mg/L. What is the chlorine demand?

7. What is the chlorine demand in mg/L, if the chlorine dose is 5.2 mg/L and the chlorine residual is 0.3 mg/L?

8. If an operator feeds a chlorine dosage of 1.8 mg/L and the system has a chlorine demand of 1.3 mg/L, what would the final chlorine residual be?

9. What is the chlorine residual, if the chlorine demand is 2.3 mg/L and the chlorine dose is 3.4 mg/L?

10. What is the chlorine demand if the chlorine residual is 1.2 mg/L and 4.7 mg/L of chlorine has been added?

FLUORIDATION

Use the following table to calculate all four different types of fluoridation problems.

Note: This table can be found, along with the formulas, on your formula sheet.

Chemical	Formula	Available Fluoride Ion (AFI) Concentration	Chemical Purity
Sodium Fluoride	NaF	0.453	98%
Sodium Fluorosilicate	Na_2SiF_6	0.607	98%
Fluorosilicic Acid	H_2SiF_6	0.792	23%

Formulas:

$$\text{Fluoride Feed Rate (lbs/day)} = \frac{\text{Dose (mg/L) X Capacity (MGD) X 8.34 lbs/gal}}{\text{Available Fluoride Ion (AFI) X Chemical Purity (as decimal)}}$$

$$\text{Fluoride Feed Rate (gpd)} = \frac{\text{Dose (mg/L) X Capacity (gpd)}}{\text{18,000 mg/L}}$$

$$\text{Dosage (mg/L)} = \frac{\text{Solution fed (gal) X 18,000 mg/L}}{\text{Capacity (gpd)}}$$

$$\text{Dosage (mg/L)} = \frac{\text{Fluoride Feed Rate (lbs/day) X (Available Fluoride Ion) X (Chemical Purity)}}{\text{Capacity (MGD) X 8.34 lbs/gal}}$$

Example: A water plant produces 2.88 MGD and the city wants to add 1.1 mg/L of fluoride using sodium fluorosilicate, Na_2SiF_6. The commercial purity of the sodium fluorosilicate is 98.5% and the percent fluoride ion content of Na_2SiF_6 is 60.7%. What is the amount of added sodium fluorosilicate in lbs/day?

$$\text{Fluoride Feed Rate (lbs/day)} = \frac{\text{Dose (mg/L) X Capacity (MGD) X 8.34 lbs/gal}}{\text{Available Fluoride Ion (AFI) X Chemical Purity (as decimal)}}$$

$$= \frac{\text{(1.1 mg/L) X (2.88 MGD) X (8.34 lbs/gal)}}{(0.607)(0.985)}$$

$$= \frac{26.42}{0.60} \text{ lbs/day}$$

$$= 44 \text{ lbs/day}$$

Example: A water plant produces 1.0 MGD and has less than 0.1 mg/L of natural fluoride. What would the fluoride feed rate of sodium fluoride need be to obtain a 1.0 mg/L in the water?

$$\text{Fluoride Feed Rate (gpd)} = \frac{\text{Dose (mg/L) X Capacity (gpd)}}{\text{18,000 mg/L}}$$

$$= \frac{\text{(1.0 mg/L) X (1 MGD)}}{\text{18,000 mg/L}} \text{ X } \frac{\text{(1,000,000 gal)}}{\text{(1 MG)}}$$

$$= 55.6 \text{ gpd}$$

Example: A plant uses 10 gallons of sodium fluoride from its saturator in treating 200,000 gallons of water. What is the calculated dosage?

$$\text{Dosage (mg/L)} = \frac{\text{Solution fed (gal) X 18,000 mg/L}}{\text{Capacity (gpd)}}$$

$$= \frac{(10\ \text{gal})\ \text{X}\ (18{,}000\ \text{mg/L})}{200{,}000\ \text{gal}}$$

$$= \frac{180{,}000}{200{,}000}\ \text{mg/L}$$

$$= 0.9\ \text{mg/L}$$

Example: A water plant uses 43 pounds of fluorosilicic acid in treating 1,226,000 gallons of water. Assume the acid has 23 percent purity. What is the calculated dosage?

$$\text{Dosage (mg/L)} = \frac{\text{Fluoride Feed Rate (lbs/day) X (Available Fluoride Ion) X (Chemical Purity)}}{\text{Capacity (MGD) X 8.34 lbs/gal}}$$

$$= \frac{(43\ \text{lbs/day})\ \text{X}\ (0.792)\ \text{X}\ (0.23)}{(1.226\ \text{MGD})\ \text{X}\ (8.34\ \text{lb/gal})}$$

$$= \frac{7.83}{10.22}\ \text{mg/L}$$

$$= 0.77\ \text{mg/L}$$

EXERCISES (Fluoridation):

1. A plant uses 19 gallons of solution from its saturator in treating 360,000 gallons of water. What is the calculated dosage?

2. A plant uses 65 pounds of sodium fluorosilicate in treating 5.54 MG of water in one day. What is the calculated dosage?

3. A water plant produces 2,000 gpm and the city wants to add 1.1 mg/L of fluoride using sodium fluorosilicate, Na_2SiF_6. What is the feed rate in lbs/day?

4. A water plant produces 250,000 gpd and has a natural fluoride of 0.4 mg/L. If the plant were using sodium fluoride, what would the fluoride feed rate be in gpd to obtain a 1.0 mg/L in the water?

5. You treat a volume of 2,035,000 gallons of water with 40 pounds of Fluorosilicic Acid during one day. What is the calculated dosage?

6. Calculate the dosage if a plant uses 40 gallons of solution from its saturator to treat 0.25 MG of water.

7. What would the fluoride feed rate be to obtain a dose of 1.5 mg/L, if the plant uses sodium fluoride, produces 500,000 gpd and has a natural fluoride of <0.1 mg/L?

8. A water plant wants to use sodium fluorosilicate to add 0.9 mg/L of fluoride to their water. If the plant produces 3,300 gpm, what is the feed rate in lbs/day?

POTASSIUM PERMANGANATE

Potassium permanganate ($KMnO_4$) limits the amount of iron and manganese that enters the distribution center. Water operators need to be able to calculate the required dose of potassium permanganate, so that the correct dose can be added to the water. The required dosage is found by adding the raw water's existing iron concentration and twice the existing manganese concentration. The final dose is expressed as mg/L.

Formula: Dose (mg/L) = 1(Iron concentration mg/L) + 2(Manganese concentration mg/L)

Example: A water system's analytical results indicate an iron level of 3.2 mg/L and a manganese level of 0.53 mg/L. Determine the estimated demand of potassium permanganate.

$KMnO_4$ dose = 1(3.2) + 2(0.53)
= 4.26 mg/L

This formula can also be used to determine the amount of potassium permanganate used in a given time period.

Example: Your raw water measures manganese levels of 0.5 mg/L and total iron levels of 0.2 mg/L. How many pounds of potassium permanganate should be fed to treat 2 MG per day for only iron and manganese?

$KMnO_4$ dose = 1(0.2) + 2(0.5)
= 1.2 mg/L

Total $KMnO_4$ Required = (1.2 mg/L) X (8.34) X (2 MG)
= 20.0 lbs

EXERCISES (Potassium Permanganate):

1. A raw water analysis shows an iron level of 2.46 mg/L and a manganese level of 1.03 mg/L. What is the demand for potassium permanganate?

2. Your water system is recording iron concentrations of 1.82 mg/L and manganese concentrations of 0.68 mg/L in your raw water. What is the $KMnO_4$ demand?

3. A water system is reporting an iron concentration of 8.2 mg/gallon and a manganese concentration of 5.0 mg/gallon. What is the demand for potassium permanganate?

4. Raw water measures manganese levels of 0.42 mg/L and total iron levels of 0.15 mg/L. How many pounds of potassium permanganate should be fed to treat 0.2 MG per day for only iron and manganese?

5. If raw water has a 0.36 mg/L iron concentration and a 1.27 mg/L manganese concentration. How many pounds of KMnO4 are needed to treat 100,000 gallons per day for only iron and manganese?

ADMINISTRATIVE DUTIES

Administrative duties that water system operators may encounter include estimating project costs, budgeting, and inventory control. Operators need to estimate the cost of projects for budgeting purposes or to determine if the funds on hand are sufficient to complete the project. Project costs consist of two primary components; labor costs and material costs.

Budgeting is the process used by utilities to estimate total operating costs for the future. Budgets are commonly expressed as a percentage of the previous year's cost. Inventory control is the process by which materials and supplies are purchased and stored to insure that these materials and supplies are available to the utility when they are needed.

Basic math functions, along with some judgment and common sense, are used to solve these types of problems. The following examples illustrate issues related to administrative duties.

Example:
An employee receives an hourly wage of $17.50. For each hour worked over 40 hours per week, overtime is paid at the rate of 1.5 times the hourly rate. If an employee works 52 hours during a week what it the total pay that the employee should receive?

Overtime hours = Total hours – Regular hours
= 52 hours – 40 hours
= 12 hours (overtime)

Regular pay = 40 hours x $17.50/hour = $700.00

Overtime wage = $17.50/hour x 1.5 = $26.25/hour

Overtime pay = 12 hours x $26.25/hour = $315.00

Total pay = Regular pay + Overtime pay
= $700.00 + $315.00
= **$1,015.00**

Example:
The current annual operating budget for a water treatment plant is $650,000. Fifty-five percent of the budget represents salary costs and the remainder represents all other expenses including: utilities, supplies, billing, and administration. It is estimated that salary costs will increase by 4.5% and all other expenses will increase by 6.0% for the next year. Calculate the budget for the next year.

Calculate the salary costs and other costs.
Current salary = $650,000 x 0.55 = $357,500

Other costs = $650,000 - $357,500 = $292,500

Calculate future salary costs.
$357,500 x 0.045 = $16,087.50

$357,500 + $16,087.50 = $373,587.50

Calculate future other costs.
$292,500 x 0.060 = $17,550

$292,500 + $17,550 = $310,050

Total future budget costs = $373,587.50 + $310,050 = **$683,637.50**

Example:
The water utility installs an average 250 linear feet of 8-inch diameter water main per week. A 12 week reserve supply is required at all times to respond to a major water system repair. It takes 6 weeks to obtain a new supply of pipe after an order. What is the minimum inventory required before ordering additional pipe?

Time required to receive pipe after ordered = Reserve period + Order period
= 12 weeks + 6 weeks = 18 weeks

Minimum inventory = Number of weeks x Pipe required per week
= 18 weeks x 250 ft/week = **4,500 ft**

MISCELLANEOUS SAMPLE PROBLEMS

The following problems are designed to use all of the information you have learned to this point. Problems may require multiple steps using different formulas to arrive at the answers. Answers are given for each problem in the back of the book. If your answer differs, but is close, it may be in the way the calculation was rounded at some point.

1. What is the area of the water surface in a tank that measures 25 feet wide and 32 feet long?

2. What is the area in square inches of a 10 inch ductile iron pipe?

3. What is the circumference of a standpipe that has a radius of 22 feet a height of 200 feet?

4. What is the volume in cubic feet of a tank that measures 50 feet long, 35 feet wide and is 12 feet deep?

5. What is the volume in gallons of a circular tank that measures 50 feet in diameter and has a sidewall depth of 18 feet?

6. What is the detention time of a tank that measure 45 feet in diameter and has depth of 22 feet? The flow to the tank is 2300 gpm.

7. How many pounds of chlorine would it take to raise the residual of the above tank to 50 ppm?

8. Calcium hypochlorite is 70 percent available chlorine. How many pounds would be required to raise the residual of 400,000 gallons of water to 50 ppm?

9. Determine the flow in cubic feet per second if the velocity in a 12 inch pipe is 4 feet per second?

10. Last month your system pumped 7,106,300 gallons of water into the distribution system. Your system was able to account for 5,264,800. What was your % unaccounted for water that month?

11. Your water treatment plant currently treats water at a rate of 700 gpm. How many MGD is this?

MISCELLANEOUS SAMPLE PROBLEMS (continued)

12. Your clear well pump delivers 750 GPM to your main water storage tank. The demand for water for this tank is approximately six million gallons per week. How many hours will you need to run the pump per week to meet the demand?

13. To accurately obtain a chlorine residual from your system, you are sampling from a customers tap. You would like to flush twice the volume of the service line before sampling. The service line is ¾” and approximately 200 feet from the main. How many gallons must you flush?

14. You have replaced ¾ of the meters in your system. You have a total of 540 meters. How many will you need to complete the task of replacing all of the meters?

15. 77° F is the same temperature as how many degrees C?

16. If chlorine costs $0.53/lb, what is the daily cost to chlorinate 7 MGD of water to an initial concentration of 2.3 mg/L?

17. How many gallons of sodium hypochlorite (12.5%) are required to disinfect an 3-inch water line 1500 feet long using the dosage of 50 mg/L?

18. If a hypochlorinator (treating well water) is set at a pumping rate of 10 gpd and uses an 18% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 160 GPM?

SAMPLE QUIZ

Addition, Subtraction, Multiplication & Division

1. If a water distribution system is made up a 4,322 feet of 6-inch water line, 2,105 feet of 4-inch water line and 788 feet of 2-inch water line, how many feet of water line total is in the system?
   A. 6,215
   B. 7,215
   C. 6,115
   D. 7,205

2. The water level in a water storage reservoir drops an average of 3 feet per day. If the water level began at 57 feet, what is the water level after 6 days?
   A. 18 feet
   B. 54 feet
   C. 39 feet
   D. 21 feet

3. A water system serves 48 residential connections each of which use an average of 280 gallons per day. How many gallons total in the system are used each day?
   A. 13,440
   B. 3,280
   C. 11,200
   D. 9,600

4. Last year the water system used 96 gallons of chlorine solution. On average, how many gallons of chlorine solution were used each month?
   A. 48
   B. 9
   C. 12
   D. 8

5. If 2 feet of head is lost per 1,700 feet of water line, how many feet of head are lost in a water line that is 13,600 feet long?
   A. 8
   B. 10
   C. 16
   D. 15

6. A water system bills at a rate of $0.65/1,000 gallons for the first 10,000 gallons; $0.40/1,000 gallons for the next 12,500 gallons; and $0.20/1,000 gallons for everything over 22,500 gallons. If a customer uses 30,000 gallons, how much is the water bill?
   A. $2.55
   B. $6.00
   C. $10.55
   D. 13.00

7. Convert 0.92 to a percentage.
   A. 9.2%
   B. 0.92%
   C. 920%
   D. 92%

8. A water system has a total of 425 connections, 16% of which are commercial. How many commercial connections are there?
   A. 27
   B. 124
   C. 6800
   D. 68

9. A water system diverts 1/3 of its total water supply to a RO treatment unit which reduces the total dissolved solids in the water. If the total water supply for the system is 870,000 gallons per day, how many gallons per day are being treated?
   A. 580,000
   B. 290,000
   C. 435,000
   D. 870,000

10. During a typical day, 42% of the total storage capacity in a water system is used. If the system has a storage capacity of 350,000 gallons, how many gallons are remaining at the end of each day?
   A. 85,260
   B. 147,000
   C. 164,333
   D. 203,000

11. You have been asked to report the unaccounted for water in your system. Your plant produced 7.23 MG last month, and the meter readings indicate 5.84 MG was billed. The flushing program used 30,000 gallons, and the local fire department used 20,000. What is your percentage of unaccounted water?
   A. 1.34%
   B. 18.5%
   C. 19.2%
   D. 19.9%

Unit Conversions

12. Convert 2,000 gallons into cubic feet.
   A. 8,000
   B. 14,960
   C. 200
   D. 267

13. The cross sectional area of a pipe is 200 square inches. What is the cross sectional area of that pipe in square feet?

A. 1.4
B. 17
C. 20
D. 9.5

14. The flow rate in a pipe is measured at 500 gallons/minute. Convert that flow rate into cubic feet/minute.

A. 2.8
B. 3,740
C. 1.1
D. 67

15. A storage tank is filling at a rate of 10.7 feet per hour. What is the fill rate in feet per minute?

A. 20
B. 1
C. 0.2
D. 0.4

Area Calculations

16. If a water pipe is 10 inches in diameter, what is the cross sectional area of that pipe in square inches?

A. 78.5
B. 19.6
C. 7.5
D. 100

17. A tank is 20 feet tall and 12 feet in diameter. What is the area of the top of the tank in square feet?

A. 240
B. 314
C. 452
D. 113

18. If a water pipe is 18 inches in diameter and 2 miles long, what is the cross sectional area of that pipe in square feet?

A. 85
B. 254
C. 1.8
D. 21

Volume Calculations

19. If a water reservoir is 200 feet long, 275 feet wide and 12 feet deep, what is the volume of water it can hold in cubic feet?

A. 660,000
B. 33,000
C. 55,000
D. 4870

20. If a water tank is 50 feet in diameter and 30 feet tall, long, what is the volume of water it can hold in gallons?

A. 109,956
B. 58,800
C. 235,502
D. 440,385

21. If a water tank has a diameter of 20 feet and is 85 feet tall, how much water in gallons can the tank hold?

A. 26,690
B. 199,641
C. 13,345
D. 432,154

22. If a water pipe is 1.5 feet in diameter and 6850 feet long, what is the volume of the pipe in gallons?

A. 76,900
B. 90,499
C. 12,110
D. 9,050

23. A water tank is designed to hold enough water to a water system for 2 days without being refilled. If the water system has 318 connections and each connection uses 115 gallons per day, how many gallons should the tank hold in gallons?

A. 36,570
B. 1,200
C. 73,140
D. 38,600

Flow Rate Calculations

24. If a water plant treats 1.6 million gallons per day, what is the flow rate out if the plant in gallons/minute?

A. 2304
B. 1111
C. 110
D. 987

25. Water in a 10-inch pipe is moving at 2.5 ft/sec. What is the flow rate in the pipe in gal/min?

A. 82
B. 606
C. 1515
D. 10

26. A well which supplies a water system has a constant chlorine demand of 2.3 mg/L. If the operator wants to maintain a residual of 1.1 mg/L, what many mg/L should the operator dose with?

A. 1.2
B. 3.4
C. 4.5
D. 2.8

27. A rural water system requires 30 lbs/day of chlorine to disinfect its water supply. If the operator uses a 15% sodium hypochlorite solution, how many pounds per day will he need to use?

A. 300
B. 285
C. 35
D. 200

28. A water plant processes 903 gal/min. If the chlorine dose added to the water is 2.4 mg/L, how many pounds of chlorine are used each day?

A. 290
B. 57
C. 195
D. 26

29. A water plant processes 0.87 MGD, if the chlorine dose added to the water is 3.0 mg/L, how many pounds of a 12% sodium hypochlorite solution are used each day?

A. 183
B. 17
C. 145
D. 20

30. A new installed 12-inch diameter line that is 4050 feet long needs to be disinfected. The operator fills that pipe with water and adds 10 pounds of 5% sodium hypochlorite solution to disinfect the line. What is the chlorine dose in the pipe in mg/L?

A. 50
B. 2.5
C. 0.25
D. 38

CLASS I MATH EXAM PREP – IN CLASS

1. A water sample has the following results:
   Bromodichloromethane 0.018 mg/L,
   Chloroform 0.038 mg/L,
   Bromoform 0.002 mg/L,
   Dibromochloromethane 0.006mg/L.

2. What is the chlorine demand if the water has a chlorine dose of 2.5 mg/L and the residual is 0.2 mg/L?

3. Calculate drawdown, in feet, using the following data. The water level in a well is 21 feet below the ground surface when the pump is not in operation. The water level is 37 feet below the ground surface when the pump is in operation.

4. A water system bills at a rate of $0.70/1,000 gallons for the first 10,000 gallons; $0.55/1,000 gallons for the next 15,000 gallons; and $0.35/1,000 gallons for all over 25,000 gallons. If a customer uses 37,000 gallons, how much is the water bill?

5. What is the average fluoride reading over the past week: 0.85 mg/L, 0.72 mg/L, 0.81 mg/L, 1.19 mg/L, 0.99 mg/L, 0.71 mg/L?

6. What is the 90th percentile for lead content? The analytical results of the lead content of your water supply show the following results:
   0.007 mg/L, 0.016 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L

7. The beginning reading of a master meter reads 8,324,844 and seven days later this same meter reads 27,017,998. What is the total gallons pumped and what is the daily average?

8. Last month your Water System pumped 5,106,300 gallons of water into the distribution system. Your system was able to account for 3,264,800 gallons. What was your unaccounted for % of water for this month?

9. During a 30 day period a booster station pumped 23,720 gallons of water to an isolated pressure zone. During the same period the customers of the zone were billed for a total of 15,630 gallons of water used. Also during this period the high service pumps produced 5,200,000 gallons into the distribution system. What is the water loss percentage for the pressure zone?

10. Your system is preparing to apply for a rate increase and the PSC is asking about your "unaccounted for water" for the month of July. Your plant produced 5.18 MG in July and the meter readings indicate 4.68 MG was billed. You have been informed that the fire department hauled 50,000 gallons to farmers and the hydrant flushing program used 40,000 gallons. What would you report as the unaccounted for water?

11. In 25 pounds of 70 percent calcium hypochlorite there are:

12. A distribution booster station operates 14 hours per day. The system requires that the water must be re-chlorinated and expects to use 16 lbs of Cl_2 per day. The booster station pumps 500 gpm. The operator should set the chlorine feed rate at:

13. Convert 70°F is what in Celsius?

14. A temperature measured 25°C is what in Fahrenheit?

15. A 3.27% chlorine solution is what concentration in mg/L?

16. Convert 10.8 grains per gallon to mg/L of hardness:

17. The elevation of water in the tank is at 1,500 feet, the elevation of the pump is 600 feet. What is the gauge pressure at the pump?

18. Two columns of water are filled completely at sea level to a height of 78 feet. Column A is 0.5 inches in diameter. Column B is 5 inches in diameter. What will two pressure gauges, one attached to the bottom of each column read?

19. A water treatment plant used 62 chlorine cylinders during one year of operation. The average withdrawal from each cylinder was 142 lbs. What was the total number of pounds of chlorine used for the year?

20. A chemical pump is calibrated by timing to deliver 450 milliliter in 15 seconds. How much chemical is being added in gallons per minute?

21. A leak of one (1) pint per minute is discovered. How many gallons is this per year.

22. A container weighing 45 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 152 grams after 2 minutes. What is the dosage in lbs/day?

23. If a 25 foot tall tank with a 70 foot diameter contains 15 feet of water, calculate the volume of water in gallons.

24. Your utility is laying 7,000 feet of 12 inch main to a remote area of your distribution system. Average flow to this area is expected to be 0.015 MGD. What will be the average detention time (in days) for water in 12 inch main?

25. Find the detention time in hours in a tank that measures 70 ft long by 55 ft wide and 25 ft deep with a flow to the tank of 1,500 gpm.

26. A clearwell is 10 ft deep, 15 ft wide, and 40 feet long. If the flow through the clearwell is 0.40 MGD, what is the detention time in hours?

27. How many hours would it take to use the water in a 250,000 ft. 8 inch pipe with an outflow of 1,500 gpm in an inflow of 500 gpm?

28. What amount of 100% chlorine is required to treat 0.20 million gallons of water to provide a 0.9 mg/L dose?

29. How many pounds of chlorine gas are required to treat 200 gpm of water to provide a 1.2 mg/L residual?

30. A chlorinator is set to feed 10 pounds of chlorine in 24 hours to a flow of 0.5 MGD. Find the chlorine dose in mg/L.

31. Examination of the raw water shows manganese levels of 0.4 mg/L and total iron levels of 0.3 mg/L. How many pounds of potassium permanganate should be fed to treat 200,000 gallons per day for only iron and manganese?

32. If chlorine costs $0.47/lb, what is the daily cost to chlorinate 2.5 MGD of water to an initial concentration of 1.6 mg/L?

33. A rectangular reservoir 100 ft x 50 ft x 15 ft is filled with water. How many pounds of alum must be added in order to produce a dosage of 50 mg/L?

34. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line 2,000 feet long using dosage of 50 mg/L chlorine?

35. Water from a well is being treated by hypochlorinator. If the hypochlorinator is set at a pumping rate of 6 gpd and uses a 12% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 180 GPM?

36. A water plant uses 20 gallons of sodium fluoride solution in treating 0.45 MGD of water. Natural fluoride ion is 0.25 mg/L. What is the calculated dosage?

37. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 200,000 gallons of water. The raw water has a natural fluoride content of 0.2 mg/L and the desired fluoride in the finished water is 1.2 mg/L. How many gallons of feed solution is needed?

38. A diaphragm pump feeds a polyphosphate to the clearwell to treat for iron and manganese. At 100% the pump will put out 150 mL per min. The operator must treat a plant flow of 0.50 MGD with 2.5 mg/L of polyphosphate. The polyphosphate weighs approximately 12 lbs/gallon. What is the pump setting?

39. The average chlorine residual entering a booster station is 0.3 mg/L. Using a gas chlorine feed system on site, the operator must boost the chlorine to a residual of 2.2 mg/L. The booster pump rated at 0.25 MGD runs 16 hours per day. How many pounds of Cl_2 will be fed per day?

CLASS I MATH EXAM PREP – HOMEWORK

1. A water sample has the following results:
   Bromodichloromethane 0.025 mg/L,
   Chloroform 0.045 mg/L,
   Bromoform 0.002 mg/L,
   Dibromochloromethane 0.006mg/L.

2. What is the chlorine demand if the water has a chlorine dose of 2.3 mg/L and the residual is 0.7 mg/L?

3. Calculate drawdown, in feet, using the following data. The water level in a well is 21 feet below the ground surface when the pump is not in operation. The water level is 58 feet below the ground surface when the pump is in operation.

4. A water system bills at a rate of $0.80/1,000 gallons for the first 10,000 gallons; $0.45/1,000 gallons for the next 15,000 gallons; and $0.30/1,000 gallons for all over 25,000 gallons. If a customer uses 36,000 gallons, how much is the water bill?

5. What is the average fluoride reading over the past week: 0.85 mg/L, 0.72 mg/L, 0.84 mg/L, 1.09 mg/L, 0.92 mg/L, 0.51 mg/L?

6. What is the 90th percentile for lead content? The analytical results of the lead content of your water supply show the following results:

   0.007 mg/L, 0.016 mg/L, 0.021 mg/L, <0.002 mg/L and 0.010 mg/L

7. The beginning reading of a master meter reads 6,324,844 and seven days later this same meter reads 29,017,998. What is the total gallons pumped and what is the daily average?

8. Last month your Water System pumped 7,106,300 gallons of water into the distribution system. Your system was able to account for 5,764,800 gallons. What was your unaccounted for % of water for this month?

9. During a 30 day period a booster station pumped 22,625 gallons of water to an isolated pressure zone. During the same period the customers of the zone were billed for a total of 18,640 gallons of water used. Also during this period the high service pumps produced 5,200,000 gallons into the distribution system. What is the water loss percentage for the pressure zone?

10. Your system is preparing to apply for a rate increase and the PSC is asking about your "unaccounted for water" for the month of July. Your plant produced 5.18 MG in July and the meter readings indicate 4.48 MG was billed. You have been informed that the fire department hauled 50,000 gallons to farmers and the hydrant flushing program used 40,000 gallons. What would you report as the unaccounted for water?

11. In 25 pounds of 65 percent calcium hypochlorite there are:

12. A distribution booster station operates 14 hours per day. The system requires that the water must be re-chlorinated and expects to use 20 lbs of Cl_2 per day. The booster station pumps 500 gpm. The operator should set the chlorine feed rate at:

13. Convert 72°F is what in Celsius?

14. A temperature measured 29°C is what in Fahrenheit?

15. A 4.75 chlorine solution is what concentration in mg/L?

16. Convert 10.8 grains per gallon to mg/L of hardness:

17. The elevation of water in the tank is at 1,500 feet, the elevation of the pump is 650 feet. What is the gauge pressure at the pump?

18. Two columns of water are filled completely at sea level to a height of 72 feet. Column A is 0.5 inches in diameter. Column B is 5 inches in diameter. What will two pressure gauges, one attached to the bottom of each column read?

19. A water treatment plant used 62 chlorine cylinders during one year of operation. The average withdrawal from each cylinder was 146 lbs. What was the total number of pounds of chlorine used for the year?

20. A chemical pump is calibrated by timing to deliver 550 milliliter in 15 seconds. How much chemical is being added in gallons per minute?

21. A leak of one (1) pint per minute is discovered. How many gallons is this per year.

22. A container weighing 45 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 185 grams after 2 minutes. What is the dosage in lbs/day?

23. If a 25 foot tall tank with a 70 foot diameter contains 21 feet of water, calculate the volume of water in gallons.

24. Your utility is laying 4,500 feet of 12 inch main to a remote area of your distribution system. Average flow to this area is expected to be 0.025 MGD. What will be the average detention time (in days) for water in 12 inch main?

25. Find the detention time in hours in a tank that measures 75 ft long by 55 ft wide and 25 ft deep with a flow to the tank of 2,000 gpm.

26. A clearwell is 10 ft deep, 15 ft wide, and 50 feet long. If the flow through the clearwell is 0.50 MGD, what is the detention time in hours?

27. How many hours would it take to use the water in a 175,000 ft. 8 inch pipe with an outflow of 2,500 gpm in an inflow of 500 gpm?

28. What amount of 100% chlorine is required to treat 0.25 million gallons of water to provide a 1.4 mg/L dose?

29. How many pounds of chlorine gas are required to treat 250 gpm of water to provide a 1.6 mg/L residual?

30. A chlorinator is set to feed 15 pounds of chlorine in 24 hours to a flow of 0.5 MGD. Find the chlorine dose in mg/L.

31. Examination of the raw water shows manganese levels of 0.5 mg/L and total iron levels of 0.3 mg/L. How many pounds of potassium permanganate should be fed to treat 250,000 gallons per day for only iron and manganese?

32. If chlorine costs $0.51/lb, what is the daily cost to chlorinate 2.5 MGD of water to an initial concentration of 1.4 mg/L?

33. A rectangular reservoir 100 ft x 50 ft x 25 ft is filled with water. How many pounds of alum must be added in order to produce a dosage of 50 mg/L?

34. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line 4,000 feet long using dosage of 50 mg/L chlorine?

35. Water from a well is being treated by hypochlorinator. If the hypochlorinator is set at a pumping rate of 16 gpd and uses a 12% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 280 GPM?

36. A water plant uses 25 gallons of sodium fluoride solution in treating 0.40 MGD of water. Natural fluoride ion is 0.25 mg/L. What is the calculated dosage?

37. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 275,000 gallons of water. The raw water has a natural fluoride content of 0.2 mg/L and the desired fluoride in the finished water is 1.5 mg/L. How many gallons of feed solution is needed?

38. A diaphragm pump feeds a polyphosphate to the clearwell to treat for iron and manganese. At 100% the pump will put out 250 mL per min. The operator must treat a plant flow of 0.75 MGD with 2.5 mg/L of polyphosphate. The polyphosphate weighs approximately 12 lbs/gallon. What is the pump setting?

39. The average chlorine residual entering a booster station is 0.2 mg/L. Using a gas chlorine feed system on site, the operator must boost the chlorine to a residual of 2.2 mg/L. The booster pump rated at 0.20 MGD runs 16 hours per day. How many pounds of Cl_2 will be fed per day?

CONGRATULATIONS.

You've finished the Class I section of the handbook.
You now know every type of problem that will be on the Class I test.

If you are taking the Class II test, please turn to the next page to continue.

ALKALINITY

As a water operator, it is important to know a water sample's alkalinity. Alkalinity is the water's capacity to neutralize acids or the measure of how much acid can be added to a liquid without causing a significant change in pH. It is expressed in terms of mg/L of equivalent calcium carbonate.

Formula: Alkalinity (mg/L as $CaCO_3$) = $\frac{\text{mL of } H_2SO_4 \times 1{,}000}{\text{mL of sample}}$

Example: A 75 mL sample is titrated with 0.02 M H_2SO_4. The endpoint is reached when 17.5 mL of H_2SO_4 have been added. What is the alkalinity concentration?

Alkalinity (mg/L as $CaCO_3$) = $\frac{\text{mL of } H_2SO_4 \times 1{,}000}{\text{mL of sample}}$

= (17.5 mL X 1000) / (75)

= 233.3 mg/L as $CaCO_3$

HARDNESS

Hardness is the measure of dissolved salts in alkaline water. To measure hardness, a water operator needs to know how many mL of ethylenediaminetetraacetic acid (EDTA) it would take to neutralize the salts. This allows you to determine how much hardness was neutralized. Hardness is also measured in mg/L of equivalent calcium carbonate.

Formula: Hardness (mg/L as $CaCO_3$) = $\frac{\text{mL of EDTA} \times 1{,}000}{\text{mL of sample}}$

Example: A 100 mL sample is titrated with 0.02 M EDTA. The endpoint is reached when 18.2 mL of EDTA have been added. What is the hardness concentration?

Hardness (mg/L as $CaCO_3$) = $\frac{\text{mL of EDTA} \times 1{,}000}{\text{mL of sample}}$

= (18.2 X 1,000) / (100)

= 182 mg/L as $CaCO_3$

EXERCISES (Alkalinity/Hardness):

1. A 45 mL sample is titrated with 0.01 M H_2SO_4. The endpoint is reached when 13.9 mL of H_2SO_4 have been added. What is the alkalinity concentration?

2. A 100 mL sample is titrated with 0.02 M H_2SO_4. The endpoint is reached when 21.4 mL of H_2SO_4 have been added. What is the alkalinity concentration?

3. A 65 mL sample is titrated with 0.03 M EDTA. The endpoint is reached when 15.3 mL of EDTA have been added. What is the hardness concentration?

4. A 115 mL sample is titrated with 0.02 M EDTA. The endpoint is reached when 23.6 mL of EDTA have been added. What is the hardness concentration?

FILTRATION/BACKWASH

Filtration is a key aspect of operating a water treatment plant. Filtration allows for the removal of solids and coagulates in the treatment process.

Calculating Filtration Rate

Filtration rate is the pace at which water is going through a given filter. It is measured in gallons per minute that cross the surface (in square feet) of the filter.

Formula: Filtration Rate (gpm/ft^2) = $\frac{\text{flow, gpm}}{\text{Surface Area ft}^2}$

Example: A treatment plant has 2 filters that treat a flow of 950 gpm. If the filters are 7 feet wide by 12 feet long, what is the loading rate on the filters in gpm/ft^2?

Filtration Rate (gpm/ft^2) = (flow, gpm) / (Surface Area ft^2)
= (950 gpm) / (12 X 7 ft^2)
= 11.3 gpm/ft^2

Calculating Backwash Water

Backwash water is the measure of total gallons used in a single backwashing. It is important for a water operator to be able to calculate this figure, so that he or she can keep track of total water used. Otherwise, water accountability will be inflated.

Formula: Backwash Water, gal = (Backwash Flow, gpm)(Backwash time, min)

Example: A 10-minute back wash at your plant uses 13 gpm. How much backwash water is used?

Backwash Water, gal = (Backwash Flow, gpm)(Backwash time, min)
= 13 gpm X 10 min
= 130 gal

Calculating Backwash Percent
Once you know how to calculate the total gallons backwashed, you can calculate what percentage of the daily water produced is being diverted for backwashing.

Formula: $$\text{Backwash, \%} = \frac{(\text{Backwash water, gal})(100\%)}{(\text{Water Filtered, gal})}$$

Example: Your backwash ratio is 22 gpm for 17 minutes each day. What percentage of your total daily production of 525,000 gallons is used for backwash?

Backwash Water, gal = (Backwash Flow, gpm)(Backwash time, min)
= (22 gpm) (17 min)
= 374 gal

Backwash % = (Backwash Water, gal X 100%) / Water Filtered, gal
= (374 gal X 100%) / 525,000 gal
= 7.1%

EXERCISES (Filtration/Backwash):

1. A treatment plant has 4 filters that treat a flow of 1735 gpm. If the filters are 9 feet wide by 16 feet long, what is the loading rate on the filters in gpm/ft^2?

2. A treatment plant has 6 filters that treat a flow of 1.8 MGD. If the filters are 7 feet wide by 15 feet long, what is the loading rate on the filters in gpm/ft^2?

3. A 12-minute back wash at your plant uses 17 gpm. How much backwash water is used?

4. A filter that is 7 feet wide by 12 feet long is backwashed for 3 minutes at a rate of 975 gpm, then for 10 minutes at a rate of 2,020 gpm and then at 975 gpm for another 3 minutes. What are the backwash volume in gal/ ft^2 and the average flow rate in gpm/ft^2?

5. Your backwash ratio is 34 gpm for 14 minutes each day. What percentage of your total daily production of 635,000 gallons is used for backwash?

6. The backwash ratio is 22 gpm per ft^2 for 12 minutes each day. The filter is 21 feet by 14 feet. What percentage of your total daily production of 775,000 gallons is used for backwash?

CLASS II MATH EXAM PREP – IN CLASS

Regulations

1. Calculate the 90th percentile for lead using the following data: 0.007 mg/L, 0.016 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L.

2. A water sample has the following results:
   Bromodichloromethane 0.018 mg/L
   Chloroform 0.038 mg/L
   Bromoform 0.002 mg/L
   Dibromochloromethane 0.006mg/L

3. The average working pressure on a water main that has just been laid will be 85 psi. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

4. Bed Rock PSD is installing a 5,000 feet of 6-inch main. How many bacteriological samples must be collected before placing the main into service?

5. During a water meter test for accuracy, 200 gallons were allowed to flow through a meter. The meter registered that 192.3 gallons flowed through the meter during the test. What is the accuracy of the meter in percent?

Conversions

6. Convert 25° Celsius to Fahrenheit

7. A 3.25% chlorine solution is what concentration in mg/L?

8. Convert 200 mg/L to grains per gallons.

9. Convert 10.8 grains per gallons to mg/L of hardness.

10. The overflow of a water tank is located 900 feet above a neighborhood fire hydrant. Not accounting for c-factor of the pipe, what is the water pressure at the hydrant when the tank is full?

11. The bottom of a standpipe tank is 1,250 above sea level. The tank has a 30 feet diameter and stands 50 feet tall and is 75% full. What is the pressure in pounds per square inch of standing water in the fire hydrant in a valley that has an elevation of 650 feet above sea level?

12. What is the smallest size pump (in gpm) that is needed to produce twice the daily average of 250,000 gpd?

13. A ferric chloride pump is calibrated by timing to deliver 420 milliliter in 15 seconds. How much coagulant is being added in gallons per minute?

14. A filter that had been in service for 3 days, filtered 3.4 MG. If the filter is 12 feet wide by 18 feet in length, what was the average flow rate through the filter in gpm?

Miscellaneous

15. A water system analytical results indicates an iron level of 1.3 mg/L and a manganese level of 0.5 mg/L. Determine the estimated demand of potassium permanganate.

16. A 50 milliliter sample is titrated with 0.01 M EDTA. The endpoint is reached when 14.2 milliliters of EDTA have been added. The hardness concentration is:

Volume

17. What is the minimum amount of water that will be used to disinfect a 10 inch main that is 20,000 feet long to 50 ppm <u>and</u> flush the main?

18. What is the minimum amount of water that will be needed to flush an 8 inch main that is 22,000 feet long for 15 minutes prior to disinfection and for 30 minutes after the water in line has been left standing for 6 hours? The water will pump at 400 gpm.

19. A water system with 17,005 feet of 14 inch mains, 8,523 feet of 8 inch mains, 12,000 feet of 6 inch distribution line, 2 storage tanks 35 feet in diameter and 28 feet high to the overflow. The clear well at the plant is 55 feet x 35 feet x 20 feet. How many gallons of water does it take to fill the system to capacity?

Detention Time

20. During a 30 minute pumping test, 2,785 gallons are pumped into a tank with a diameter of 10 feet. The water level before the pumping test was 3 feet. What is the gpm rate?

21. What is the theoretical detention time (in hours) for sedimentation basin of a 5 MGD plant with the dimensions of 50 feet by 140 feet by 10 feet?

22. An empty storage tank is 12 feet in diameter and 52 feet high. How long (in hours) will it take to fill 80% of the tank volume if a pump is discharging a constant 35 gallons per minute into the tank?

23. Calculate the detention time long (in hours) for a sedimentation tank that is 50 feet wide, 140 feet long, and 10 feet deep with a flow of 5.3 MGD.

Fluoridation

24. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 200,000 gallons of water. The raw water has a natural fluoride content of 0.2 mg/L and the desired fluoride in the finished water is 1.1 mg/L. How many gallons of feed solution is needed?

25. The natural fluoride level in the 956,000 gallons of water produced is 0.12 mg/L. The 55 gallon HFS day tank has a tare weight of 5 lbs. Eight gallons at 9.2 lbs. per gallon of the 28% HFS is being pumped daily into the clearwell. Calculate the fluoride dosage for your system.

26. Your EW-80 indicates an average of 5.3 pounds per day of granular sodium fluoride has been added to the average of 155,000 gallons of finished water for the last 30 days. What is the dose of fluoride in the water supply.

Pounds/Dosage

27. 0.1116 lb/min of soda ash is fed into 1,525,000 gal/day of treated water. What is the soda ash dosage?

28. What is the dosage (of/where) 12 lbs of chlorine gas is added to 450,000 gallons of finished water?

29. The operator feeds 25% (W/W) liquid caustic soda to adjust the pH of the filtered water. The plant pumps 1.5 MGD and feeds the liquid at a constant rate of 37 ppm. The 25% caustic soda weighs 12 lbs per gallon. How much caustic soda by dry weight is fed in a day?

30. Determine the setting on a potassium permanganate chemical feed pump in pounds per day if the demand is determined to be 2.2 ppm, the desired permanganate residual is 0.2 ppm and the flow is 0.45 MGD.

31. A system has a well that produces 200 gpm and a 1,500 gallon storage tank. There are 105 homes on the systems and the average daily consumption is 300 gallons/home. A chlorine dosage of 1.3 ppm is maintained using 65% HTH. How many pounds of HTH must be purchased each year?

32. How many pounds of HTH (65%) are needed to disinfect at 50 ppm a 10-inch diameter line that is 20,000 feet long?

33. How many pounds of 65% HTH are needed to shock a 10 inch diameter pipe that is 2,100 feet long to 50 ppm of chlorine residual?

34. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 1 to disinfect the tank. This method requires that the tank be filled to the overflow with enough chlorine added to the water to have a 10 mg/L residual in the tank after a 24 hour retention time. The tank holds 2,500,000 gallons filled to the overflow. It has been determined that the initial chlorine dose needs to be 25 mg/L. How many pounds of HTH 65% available chlorine will it take to get the required dose?

35. A treatment plant disinfects a flow of 0.75 MGD with 8.25% sodium hypochlorite to a dose of 2.0 mg/L. The sodium hypochlorite solution has a specific gravity of 1.8. How many gallons of sodium hypochlorite will the plant use per day?

36. A chlorine pump is feeding 12% bleach (1 gallon = 9.48 pounds) at a dosage of 2.0 mg/L. If 525,000 gallons are treated in 16 hours, how many gallons per hour is the pump feeding?

Filtration/Backwash

37. A treatment plant with dual filters processes a flow of 0.75 MGD. If the filters are 10 feet wide by 10 feet in length, what is the filtration rate?

38. A treatment plant with 4 sand filters treats a flow of 2.4 MG in 24 hours with two backwashes at the end of the run. If the filters are 10 feet wide by 20 feet in length, what is the loading rate on the filters in gpm/ft^2?

39. A filter that is 10 feet wide by 15 feet in length is backwashed for 3 minutes at a low rate of 1,100 gpm, then for 9 minutes at a high rate of 2,200 gpm and then at a low rate of 1,100 gpm for 3 minutes. What was the backwash run volume in gallons per square feet and the average flow rate in gpm/ft^2 ?

40. Determine the backwash pumping rate in gpm for a filter 10 feet long by 15 feet wide if the backwash is 20 gpm per square foot?

41. What percent of your total daily production of 500,000 gallons is used for backwash? The backwash ratio is 22.5 gpm per sq ft for 15 minutes each day through a filter that is 10 feet by 10 feet.

Combination

42. You receive a bulk truckload of NaOCl and the receiving slip states the net weight is 52,360 lbs. The certificate of analysis indicates the specific gravity is 1.22 and the trade % is 16. How many gallons of NaOCl should you receive? If the quoted cost was $0.75/gal., delivered, how much will you pay for the load? If you have two empty 2,100 gallon bulk tanks and a 300 gallon day tank with 120 gallons in it, will you be able to take the entire shipment?

43. The liquid alum feed pump is set at 100% stroke and at 100% speed the pump will feed 67 gpd of solution. What speed should the pump setting be if the plant produces 3.2 MGD? The liquid alum is being dosed from the jar tests results at 10 mg/L. The liquid alum delivered to the plant contains 5.36 pound of alum per gallon of liquid solution.

44. Due to flooding in the area, the City of Bedrock is in short supply of their 5.75% hypochlorite solution. They have contacted Flintstone PSD and asked to borrow enough 15.3% hypochlorite solution to produce 750 gallons of a 5.75% solution. Determine how many gallons of water and 15.3% hypochlorite are required to produce the desired percentage. The 750 gallon day tank has a diameter of 5 feet and is 25 feet tall. The 15.3% hypochlorite solution has a specific gravity of 1.28.

45. What is the dosage in mg/L, when 6 gph of a 5.25% hypochlorite solution is fed into a flow of 450 gpm? One gallon of hypochlorite weighs 9.02 pounds.

46. During a one-week time period, the water meter indicated that 2,250,000 gallons of water were pumped. A three percent sodium hypochlorite solution is stored in a three-foot diameter plastic tank and stored in a nearby room is a partially filled one-hundred pound chlorine cylinder. During this one-week period, the level of hypochlorite in the tank dropped 2 feet 10 inches. Calculate the chlorine dose assuming the one-hundred pound cylinder has sixty pounds remaining in the cylinder?

CLASS II MATH EXAM PREP – HOMEWORK

Regulations

1. Calculate the 90th percentile for lead using the following data: 0.007 mg/L, 0.026 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L.

2. A water sample has the following results:
   Bromodichloromethane 0.028 mg/L
   Chloroform 0.038 mg/L
   Bromoform 0.002 mg/L
   Dibromochloromethane 0.006mg/L

3. The average working pressure on a water main that has just been laid will be 105 psi. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

4. Bed Rock PSD is installing a 3,500 feet of 6-inch main. How many bacteriological samples must be collected before placing the main into service?

5. During a water meter test for accuracy, 125 gallons were allowed to flow through a meter. The meter registered that 122.3 gallons flowed through the meter during the test. What is the accuracy of the meter in percent?

Conversions

6. Convert 21° Celsius to Fahrenheit

7. A 7.25% chlorine solution is what concentration in mg/L?

8. Convert 222 mg/L to grains per gallons.

9. Convert 12.4 grains per gallons to mg/L of hardness.

10. The overflow of a water tank is located 120 feet above a neighborhood fire hydrant. Not accounting for c-factor of the pipe, what is the water pressure at the hydrant when the tank is full?

11. The bottom of a standpipe tank is 1,000 above sea level. The tank has a 30 feet diameter and stands 70 feet tall and is 75% full. What is the pressure in pounds per square inch of standing water in the fire hydrant in a valley that has an elevation of 650 feet above sea level?

12. What is the smallest size pump (in gpm) that is needed to produce twice the daily average of 170,000 gpd?

13. A ferric chloride pump is calibrated by timing to deliver 520 milliliter in 15 seconds. How much coagulant is being added in gallons per minute?

14. A filter that had been in service for 3 days, filtered 2.4 MG. If the filter is 12 feet wide by 18 feet in length, what was the average flow rate through the filter in gpm?

Miscellaneous

15. A water system analytical results indicates an iron level of 1.8 mg/L and a manganese level of 0.55 mg/L. Determine the estimated demand of potassium permanganate.

16. A 50 milliliter sample is titrated with 0.01 M EDTA. The endpoint is reached when 18.2 milliliters of EDTA have been added. The hardness concentration is:

Volume

17. What is the minimum amount of water that will be used to disinfect a 10 inch main that is 18,000 feet long to 50 ppm <u>and</u> flush the main?

18. What is the minimum amount of water that will be needed to flush an 8 inch main that is 22,000 feet long for 15 minutes prior to disinfection and for 30 minutes after the water in line has been left standing for 6 hours? The water will pump at 450 gpm.

19. A water system with 7,000 feet of 14 inch mains, 8,000 feet of 8 inch mains, 12,000 feet of 6 inch distribution line, 2 storage tanks 35 feet in diameter and 28 feet high to the overflow. The clear well at the plant is 55 feet x 35 feet x 20 feet. How many gallons of water does it take to fill the system to capacity?

Detention Time

20. During a 30 minute pumping test, 3,750 gallons are pumped into a tank with a diameter of 10 feet. The water level before the pumping test was 3 feet. What is the gpm rate?

21. What is the theoretical detention time (in hours) for sedimentation basin of a 4.75 MGD plant with the dimensions of 150 feet by 40 feet by 10 feet?

22. An empty storage tank is 15 feet in diameter and 30 feet high. How long (in hours) will it take to fill 75% of the tank volume if a pump is discharging a constant 30 gallons per minute into the tank?

23. Calculate the detention time long (in hours) for a sedimentation tank that is 150 feet wide, 40 feet long, and 10 feet deep with a flow of 4.6 MGD.

Fluoridation

24. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 270,000 gallons of water. The raw water has a natural fluoride content of 0.4 mg/L and the desired fluoride in the finished water is 1.2 mg/L. How many gallons of feed solution is needed?

25. The natural fluoride level in the 1,156,000 gallons of water produced is 0.12 mg/L. The 55 gallon HFS day tank has a tare weight of 5 lbs. Seven gallons at 9.2 lbs. per gallon of the 28% HFS is being pumped daily into the clearwell. Calculate the fluoride dosage for your system.

26. Your EW-80 indicates an average of 6.3 pounds per day of granular sodium fluoride has been added to the average of 150,000 gallons of finished water for the last 30 days. What is the dose of fluoride in the water supply.

Pounds/Dosage

27. 0.0986 lb/min of soda ash is fed into 1,500,000 gal/day of treated water. What is the soda ash dosage?

28. What is the dosage (of/where) 12 lbs of chlorine gas is added to 500,000 gallons of finished water?

29. The operator feeds 25% (W/W) liquid caustic soda to adjust the pH of the filtered water. The plant pumps 1.25 MGD and feeds the liquid at a constant rate of 27 ppm. The 25% caustic soda weighs 12 lbs per gallon. How much caustic soda by dry weight is fed in a day?

30. Determine the setting on a potassium permanganate chemical feed pump in pounds per day if the demand is determined to be 2.2 ppm, the desired permanganate residual is 0.4 ppm and the flow is 0.5 MGD.

31. A system has a well that produces 250 gpm and a 1,500 gallon storage tank. There are 120 homes on the systems and the average daily consumption is 300 gallons/home. A chlorine dosage of 1.5 ppm is maintained using 65% HTH. How many pounds of HTH must be purchased each year?

32. How many pounds of HTH (65%) are needed to disinfect at 50 ppm a 10-inch diameter line that is 23,400 feet long?

33. How many pounds of 65% HTH are needed to shock a 10 inch diameter pipe that is 1,980 feet long to 50 ppm of chlorine residual?

34. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 1 to disinfect the tank. This method requires that the tank be filled to the overflow with enough chlorine added to the water to have a 10 mg/L residual in the tank after a 24 hour retention time. The tank holds 1,800,000 gallons filled to the overflow. It has been determined that the initial chlorine dose needs to be 25 mg/L. How many pounds of HTH 65% available chlorine will it take to get the required dose?

35. A treatment plant disinfects a flow of 0.9 MGD with 8.25% sodium hypochlorite to a dose of 2.0 mg/L. The sodium hypochlorite solution has a specific gravity of 1.8. How many gallons of sodium hypochlorite will the plant use per day?

36. A chlorine pump is feeding 12% bleach (1 gallon = 9.48 pounds) at a dosage of 2.0 mg/L. If 500,000 gallons are treated in 16 hours, how many gallons per hour is the pump feeding?

Filtration/Backwash

37. A treatment plant with dual filters processes a flow of 0.65 MGD. If the filters are 8 feet wide by 10 feet in length, what is the filtration rate?

38. A treatment plant with 4 sand filters treats a flow of 2.0 MG in 24 hours with two backwashes at the end of the run. If the filters are 10 feet wide by 20 feet in length, what is the loading rate on the filters in gpm/ft^2?

39. A filter that is 10 feet wide by 15 feet in length is backwashed for 3 minutes at a low rate of 1,200 gpm, then for 9 minutes at a high rate of 2,200 gpm and then at a low rate of 1,200 gpm for 3 minutes. What was the backwash run volume in gallons per square feet and the average flow rate in gpm/ft^2 ?

40. Determine the backwash pumping rate in gpm for a filter 10 feet long by 10 feet wide if the backwash is 30 gpm per square foot?

41. What percent of your total daily production of 500,000 gallons is used for backwash? The backwash ratio is 25 gpm per sq ft for 15 minutes each day through a filter that is 10 feet by 10 feet.

<u>Combination</u>

42. You receive a bulk truckload of NaOCl and the receiving slip states the net weight is 42,360 lbs. The certificate of analysis indicates the specific gravity is 1.22 and the trade % is 16. How many gallons of NaOCl should you receive? If the quoted cost was $0.75/gal., delivered, how much will you pay for the load? If you have two empty 2,100 gallon bulk tanks and a 300 gallon day tank with 120 gallons in it, will you be able to take the entire shipment?

43. The liquid alum feed pump is set at 100% stroke and at 100% speed the pump will feed 77 gpd of solution. What speed should the pump setting be if the plant produces 3.2 MGD? The liquid alum is being dosed from the jar tests results at 8 mg/L. The liquid alum delivered to the plant contains 5.36 pound of alum per gallon of liquid solution.

44. Due to flooding in the area, the City of Bedrock is in short supply of their 5.25% hypochlorite solution. They have contacted Flintstone PSD and asked to borrow enough 15.3% hypochlorite solution to produce 600 gallons of a 5.25% solution. Determine how many gallons of water and 15.3% hypochlorite are required to produce the desired percentage. The 750 gallon day tank has a diameter of 5 feet and is 25 feet tall. The 15.3% hypochlorite solution has a specific gravity of 1.28.

45. What is the dosage in mg/L, when 5 gph of a 5.25% hypochlorite solution is fed into a flow of 450 gpm? One gallon of hypochlorite weighs 9.02 pounds.

46. During a one-week time period, the water meter indicated that 2,289,000 gallons of water were pumped. A two percent sodium hypochlorite solution is stored in a three-foot diameter plastic tank and stored in a nearby room is a partially filled one-hundred pound chlorine cylinder. During this one-week period, the level of hypochlorite in the tank dropped 2 feet 8 inches. Calculate the chlorine dose assuming the one-hundred pound cylinder has sixty pounds remaining in the cylinder?

APPENDIX A - ANSWERS TO EXERCISES (Addition/Subtraction):

1. 12 + 54 = 66
2. 15 + 13 = 28
3. 23.2 + 12.6 = 35.8
4. 25.32 + 23.06 = 48.38
5. 4.36 + 102 = 106.36
6. 23.5 + 14.32 + 12.444 = 50.264
7. 123.45 + 2.3 + 10.1234 = 135.8734
8. 0.32597 + 2.684 + 18.364 = 21.37397
9. 0.36 + 0.026 + 0.005 = 0.391
10. 1.3 + 0.223 + 1.445 = 2.986
11. 72 – 54 = 18
12. 1.5 – 1.3 = 0.2
13. 23 – 12.6 = 10.4
14. 2.684 – 18.36 = -15.676
15. 6.25 – 9.5 = -3.25
16. 67.89 – 10.1 – 3.142 = 54.648
17. 6.334 – 0.087 = 6.247
18. 8.335 – 3.2589 – 1.3 = 3.7761
19. 100.23 – 5.34 – 6.789 = 88.101
20. 34 – 19.56 – 37.1 = -22.66

APPENDIX B - ANSWERS TO EXERCISES (Multiplication/Division):

1. 15 x 13 = 195
2. 23.3 x 12.6 = 293.58
3. 14.51 x 12.3 = 178.473
4. 12.3 x 39.005 = 479.7615
5. 67.89 x 10.1 = 685.689
6. 3.259 x 8.3 = 27.0497
7. 3.21 x 6.334 = 20.33214
8. 2.684 x 18.364 x (3 + 2) = 2.684 x 18.364 x 5 = 246.44488
9. (9 + 1) x (4 + 9) = 10 x 13 = 130
10. (12 + 2) x 13 = 14 x 13 = 182
11. 311 ÷ 12 = 25.9167
12. 25 ÷ 3 = 8.33
13. 250 ÷ 10 = 25
14. 1 ÷ 3 = 0.33
15. 6 ÷ 12 = 0.5
16. 0.67 ÷ 0.7 = 0.957
17. 12.54 ÷ 1.5 = 8.36
18. 25 ÷ (10 + 2) = 25 ÷ 12 = 2.083
19. (25 x 10) ÷ 12 = 250 ÷12 = 20.83
20. (25 x 10) ÷ (10 + 2) = 250 ÷12 = 20.83

APPENDIX C - ANSWERS TO EXERCISES (Addition/Subtraction/Multiplication/Division):

1. The following turbidities were recorded for a week. What was the average daily turbidity?

Day	Turbidity
Monday	8.2
Tuesday	7.9
Wednesday	6.3
Thursday	6.5
Friday	7.4
Saturday	6.2
Sunday	5.9

Answer:

$$= \frac{8.2 + 7.9 + 6.3 + 6.5 + 7.4 + 6.2 + 5.9}{7}$$

$$= \frac{48.4}{7} = 6.9$$

2. What is the average fluoride concentration based on the following readings?

Reading	Fl^- Conc.
1	0.4
2	0.8
3	0.7
4	1.0
5	0.8
6	1.1
7	1.2

Answer:

$$= \frac{0.4 + 0.8 + 0.7 + 1.0 + 0.8 + 1.1 + 1.2}{7}$$

$$= \frac{6}{7} = 0.9$$

3. The following amounts of alum were used in a treatment plant each month for a year. What was the average monthly requirement of alum?

Month	Lbs of Alum
January	464
February	458
March	455
April	450
May	461
June	465

Month	Lbs of Alum
July	481
August	483
September	476
October	166
November	461
December	463

Answer:

$$= \frac{464 + 458 + 455 + 450 + 461 + 465 + 481 + 483 + 476 + 166 + 461 + 463}{12}$$

$$= \frac{5283}{12} = 440$$

APPENDIX C - ANSWERS TO EXERCISES (Addition/Subtraction/Multiplication/Division):

4. Given the following flow rates, determine the average flow rates for a 24 hour period.

Time	MGD
0:00	1.18
2:00	1.31
4:00	1.25
6:00	1.33
8:00	1.31
10:00	1.22

Time	MGD
12:00	1.13
14:00	1.54
16:00	1.69
18:00	1.75
20:00	1.67
22:00	1.22

Answer:

$$= \frac{1.18 + 1.31 + 1.25 + 1.33 + 1.31 + 1.22 + 1.13 + 1.54 + 1.69 + 1.75 + 1.67 + 1.22}{12}$$

$$= \frac{16.6}{12} = 1.38$$

APPENDIX D - ANSWERS TO EXERCISES (Fractions/Decimals/Percentages/Exponents):

1. 3/8 + 1/8 = 4/8 = 1/2

2. 1/2 + 3/8 = 4/8 + 3/8 = 7/8

3. 2/3 + 1/5 = 10/15 + 3/15 = 13/15

4. 3/8 – 1/8 = 2/8 = 1/4

5. 1/2 – 3/8 = 4/8 - 3/8 = 1/8

6. 2/3 – 1/5 = 10/15 - 3/15 = 7/15

7. 3/8 x 1/8 = 3/64

8. 1/2 x 3/8 = 3/16

9. 2/3 x 1/5 = 2/15

10. 3/8 ÷ 1/8 = 3/8 x 8/1 = 3

11. 1/2 ÷ 3/8 = 1/2 x 8/3 = 4/3 = 1 1/3

12. 2/3 ÷ 1/5 = 2/3 x 5/1 = 10/3 = 3 1/3

13. 3/8 = 0.375

14. 1/8 = 0.125

15. 1/2 = 0.5

16. 1/5 = 0.2

17. 2^2 = 2 x 2 = 4

18. 3^3 = 3 x 3 x 3 = 27

19. 5^4 = 5 x 5 x 5 x 5 = 625

20. D^2 = D x D

21. $\sqrt{9}$ = 3

22. $\sqrt{D^2}$ = D

APPENDIX E - ANSWERS TO EXERCISES (Unit Conversions):

1. 87 sec x (1 min/60 sec) = 1.5 min
2. 1045 sec x (1 min/60 sec) = 17.4 min
3. 24 min x (60 sec/1 min) = 1440 sec
4. 15 min x (60 sec/1 min) = 900 sec
5. 109 min x (1 hr/60 min) = 1.8 hr
6. 44 min x (1 hr/60 min) = 0.7 hr
7. 2.8 hr x (60 min/1 hr) = 168 min
8. 0.5 hr x (60 min/1 hr) = 30 min
9. 13 hr x (1day/24 hr) = 0.5 day
10. 45 hr x (1day/24 hr) = 1.9 day
11. 0.5 day x (24 hr/1 day) = 12 hr
12. 3 day x (24 hr/1day) = 72 hr
13. 2 day x (1440 min/1 day) = 2880 min
14. 452 min x (1 day/1440 min) = 0.3 day
15. 250 gpm x (1MGD/694.4 gpm) = 0.4 MGD
16. 600 gpm x (1MGD/694.4 gpm) = 0.9 MGD
17. 120 gpm x (1MGD/694.4 gpm) = 0.2 MGD
18. 0.25 MGD x (694.4 gpm/1 MGD) = 174 gpm
19. 1.3 MGD x (694.4 gpm/1 MGD) = 903 gpm
20. 0.12 MGD x (694.4 gpm/1 MGD) = 83 gpm

APPENDIX E - ANSWERS TO EXERCISES (Unit Conversions) CONTINUED:

21. 1500 cuft x (7.48 gal/1 cuft) = 11,220 gal

22. 5 cuft x (7.48 gal/1 cuft) = 37 gal

23. 500 cuft x (7.48 gal/1 cuft) = 3,740 gal

24. 100 gal x (1 cuft/7.48 gal) = 13 cuft

25. 2500 gal x (1 cuft/7.48 gal) = 334 cuft

26. 45 gal x (1 cuft/7.48 gal) = 6 cuft

27. 2.5 gal x (8.34 lbs/1 gal) = 21 lbs

28. 020 gal x (8.34 lbs/1 gal) = 167 lbs

29. 110 gal x (8.34 lbs/1 gal) = 917 lbs

30. 24 lbs x (1 gal/8.34 lbs) = 3 gal

31. 53 lbs x (1 gal/8.34 lbs) = 6 gal

32. 150 lbs x (1 gal/8.34 lbs) = 18 gal

33. 20 psi x (2.31 ft/1 psi) = 46 ft

34. 100 psi x (2.31 ft/1 psi) = 231 ft

35. 75 psi x (2.31 ft/1 psi) = 173 ft

36. 100 ft x (1 psi/2.31 ft) = 43 psi

37. 50 ft x (1 psi/2.31 ft) = 22 psi

38. 500 ft x (1 psi/2.31 ft) = 216 psi

39. 90 cuft x (62.38 lbs/cuft) = 5614 lbs

40. 150 lbs x (1 cuft/62.38 lbs) = 2 cuft

APPENDIX F - ANSWERS TO EXERCISES (Temperature):

Convert the following temperatures from Fahrenheit to Celsius.

1. 32°F

   C = 0.56(°F – 32) = 0.56(32 – 32) = 0.56 (0) = 0

2. 70°F

   C = 0.56(°F – 32) = 0.56(70 – 32) = 0.56 (38) = 21

3. 50°F

   C = 0.56(°F – 32) = 0.56(50 – 32) = 0.56 (18) = 10

4. 85°F

   C = 0.56(°F – 32) = 0.56(85 – 32) = 0.56 (53) = 30

5. 43.7°F

   C = 0.56(°F – 32) = 0.56(43.7 – 32) = 0.56 (11.7) = 6.6

Convert the following temperatures from Celsius to Fahrenheit.

6. 32°C
   F = (1.8 x °C) + 32 = (1.8 x 32) + 32 = 57.6 + 32 = 89.6

7. 0°C
   F = (1.8 x °C) + 32 = (1.8 x 0) + 32 = 0 + 32 = 32

8. 10°C
   F = (1.8 x °C) + 32 = (1.8 x 10) + 32 = 18 + 32 = 50

9. 17°C

   F = (1.8 x °C) + 32 = (1.8 x 17) + 32 = 30.6 + 32 = 62.6

10. 23.4°C

    F = (1.8 x °C) + 32 = (1.8 x 23.4) + 32 = 42.1 + 32 = 74.1

APPENDIX G - EXERCISES (Area/Volume/Circumference/Perimeter):

1. What is the area of a filter that is 8 ft by 12 ft?

   Area = L x W = 8 ft x 12 ft = 96 ft^2

2. What is the area of a clearwell that has a width of 25 ft and a length of 80 ft?

   Area = L x W = 80 ft x 25 ft = 2000 ft^2

3. A tank is 10 ft long, 10 ft wide, with a depth of 5 ft. What is the area of the tank?

   Area = L x W = 10 ft x 10 ft = 100 ft^2

4. A tank has a diameter of 100 ft. What is the area?

   Area = 0.785(D^2) = 0.785(100 ft)(100 ft) = 7850 ft^2

5. What is the area of a clarifier with a diameter of 30 feet?

   Area = 0.785(D^2) = 0.785(30 ft)(30 ft) = 706.5 ft^2

6. What is the area of a tank with a radius of 20 ft?

   Diameter = 2 x radius = 2 x r = 2 x 20ft = 40 ft
   Area = 0.785(D^2) = 0.785(40 ft)(40 ft) = 1256 ft^2

7. A tank is 10 ft long, 10 ft wide, with a depth of 5 ft. What is the volume of the tank?

   Volume = L x W x H = (10 ft)(10 ft)(5 ft) = 500 ft^3

8. What is the volume of a sedimentation basin that is 12 ft long, 6 ft wide and 10 ft deep?

   Volume = L x W x H = (12 ft)(6 ft)(10 ft) = 720 ft^3

9. What is the gallon capacity of a tank with the following dimensions, 12 ft by 10 ft by 8 ft?

   Volume = L x W x H = (12 ft)(10 ft)(8 ft) = 960 ft^3 x (7.48 gal/1 ft^3)
   = 7180.8 gal

10. A tank is 25 ft wide, 75 feet long and has a water depth of 10 ft. How many gallons of water are in the tank?

    Volume = L x W x H = (25 ft)(75 ft)(10 ft) = 18,750 ft^3 x (7.48 gal/1 ft^3)
    = 140,250 gal

11. A clarifier has a diameter of 50 ft. If the depth of the water is 15 ft, what is the volume?

    Volume = 0.785(D^2) x depth = 0.785(50 ft)(50 ft)(15 ft) = 29,438 ft^3

APPENDIX G - EXERCISES (Area/Volume/Circumference/Perimeter) CONTINUED:

12. What is the volume of a piece of pipe that is 2000 ft long and has a diameter of 18 inches?

Diameter = 18 in x 1 ft/12 in = 1.5 ft
Volume = $0.785(D^2)$ x depth = 0.785(1.5 ft)(1.5 ft)(2000 ft) = 3,533 ft^3

13. A section of 6 inch main is to be filled with chlorinated water for disinfection. If 1320 ft of the pipe is to be disinfected, how many gallons of water will be required?

Diameter = 6 in x 1 ft/12 in =0.5 ft
Volume = $0.785(D^2)$ x depth x 7.48 gal/1 ft^3
= 0.785(0.5 ft)(0.5 ft)(1320 ft) x 7.48 gal/1 ft^3 = 1938 gal

14. A tank has a diameter of 100 ft. What is the circumference?

Circumference = 3.14 x Diameter = 3.14 x 100 ft = 314 ft

15. What is the circumference of a clarifier with a diameter of 30 feet?

Circumference = 3.14 x Diameter = 3.14 x 30 ft = 94.2 ft

16. What is the perimeter of a water plant with the following dimensions: 100 ft, 250 ft, 300 ft, 500 ft, and 220 ft?

Perimeter = $length^1$ + $length^2$ + $length^3$ + $length^4$ + $lenght^5$
= 100 ft + 250 ft + 300 ft + 500 ft + 220 ft
= 1,370 ft

17. What is the perimeter of a water plant with the following dimensions: 145 ft, 200 ft, 300 ft, 500 ft, and 240 ft?

Perimeter = $length^1$ + $length^2$ + $length^3$ + $length^4$ + $lenght^5$
= 145 ft + 200 ft + 300 ft + 500 ft + 240 ft
= 1,385 ft

18. Your system has just installed 2, 000 feet of 8" line. How many gallons of water will it take to fill this line?

8 in x 1 ft/12 in = 0.67 ft

Volume = .785 x $(0.67\ ft)^2$ x 2000 ft x 7.48 gal/ft^3 = 5,272 gallons

19. Your finished water storage tank is 35' in diameter and 65' high. With no water entering it the level dropped 4' in 5 hours. How many gallons of water were used in this period?

Volume = .785 x $(35\ ft)^2$ x 4 x 7.48 = 28,772 gallons

20. If a clarifier has a diameter of 68 feet, and a height of 86 feet, what is the surface area of the water within the clarifier?

Area = $0.785(68\ ft)^2$ = 3630 ft^2

APPENDIX H - ANSWERS TO EXECISES (Velocity/Flow/Detention Time):

1. Find the detention time of a tank that measures 50 feet long 30 feet wide and 10 feet deep with a flow to the tank of 1500 gpm?

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} = \frac{50 \text{ ft} \times 30 \text{ ft} \times 10 \text{ ft} \times (7.48 \text{ gal}/1 \text{ ft}^3)}{1500 \text{ gpm}} =$$

$$= \frac{15{,}000 \text{ ft}^3 \times (7.48 \text{ gal}/1 \text{ ft}^3)}{1500 \text{ gpm}} = \frac{112{,}200 \text{ gal}}{1500 \text{ gpm}} = 75 \text{ min}$$

2. The flow to a tank that is 50 ft long, 30 ft wide and 10 ft deep is 0.32 MGD. What is the detention time in hours?

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} = \frac{50 \text{ ft} \times 30 \text{ ft} \times 10 \text{ ft} \times (7.48 \text{ gal}/1 \text{ ft}^3)}{0.32 \text{ MGD}} =$$

$$= \frac{112{,}200 \text{ gal} \times (1\text{MG}/1{,}000{,}000)}{0.32 \text{ MGD}} = \frac{0.1122 \text{ MG}}{0.32 \text{ MGD}} = 0.35 \text{ day}$$

$$= 0.35 \text{ day} \times (24 \text{ hr}/1 \text{ day}) = 8.4 \text{ hours}$$

3. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet when the inflow is 1000 gpm?

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} = \frac{0.785 \times (100 \text{ ft})^2 \times 60 \text{ ft} \times (7.48 \text{ gal}/1 \text{ ft}^3)}{1000 \text{ gpm}} =$$

$$= \frac{3{,}523{,}080 \text{ gal}}{1000 \text{ gpm}} = 3523 \text{ min} \times (1 \text{ day}/1440 \text{ min}) = 2.4 \text{ days}$$

4. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet, when it starts full and is discharging 2500 gpm and has an inflow of 1500 gpm?

$$\frac{\text{Volume}}{\text{Flow}} = \frac{0.785 \times (100 \text{ ft})^2 \times 60 \text{ ft} \times (7.48 \text{ gal}/1 \text{ ft}^3)}{(2500 \text{ gpm} - 1500 \text{ gpm})} =$$

$$= \frac{3{,}523{,}080 \text{ gal}}{1000 \text{ gpm}} = 3523 \text{ min} \times (1 \text{ day}/1440 \text{ min}) = 2.4 \text{ days}$$

5. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet, when it starts 1/2 full and is discharging 2500 gpm and has an inflow of 1500 gpm?

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} = \frac{0.785 \times (100 \text{ ft})^2 \times 60 \text{ ft} \times (7.48 \text{ gal}/1 \text{ ft}^3)}{(2500 \text{ gpm} - 1500 \text{ gpm})} =$$

$$= \frac{3{,}523{,}080 \text{ gal}/2}{1000 \text{ gpm}} = \frac{1{,}761{,}540 \text{ gal}}{1000 \text{ gpm}} = 1762 \text{ min} \times (1 \text{ day}/1440 \text{ min}) = 1.2 \text{ days}$$

APPENDIX H - ANSWERS TO EXECISES (Velocity/Flow/Detention Time) CONTINUED:

6. A channel 3 ft wide has water flowing to a depth of 2.5 ft. If the velocity through the channel is 2 fps, what is the cfs flow rate through the channel?

Flow = area x velocity = length x width x velocity =
= 3 ft x 2.5 ft x 2 ft/sec = 15 ft^3/sec

7. The flow through a 6 inch diameter pipeline is moving at a velocity of 300 ft/sec. What is the cfs flow rate through the pipeline?

6 in x (1 ft/12 in) = 0.5 ft

Flow = area x velocity = 0.785 x D^2 x velocity =
= 0.785 x 0.5 ft x 0.5 ft x 300 ft/sec = 59 ft^3/sec

8. If a pipe has a 1-ft diameter, what is the velocity of the water if the pipe is carrying 2ft^3/sec?

velocity = flow/area = flow/(0.785 x D^2)
= (2 ft^3/sec)/(0.785)(1 ft)^2 = 2.55 ft/sec

9. A sedimentation tank holds 80,000 gallons and the flow into the plant is 855 gpm. What is the detention time in minutes?

. $$\text{D.T.} = \frac{\text{Vol}}{\text{Flow}} = \frac{80{,}000}{855} = 94 \text{ min}$$

10. What is the detention time in a sedimentation basin 80 ft long, 20 ft wide and 10 ft high if the rate of flow is 5800 gal/min?

Volume = L x W x H = 80 ft x 20 ft x 10 ft = 16,000 ft^3

flow (ft^3/min) = (5800 gal/min) / (7.48 gal/ft^3) = 775 ft^3/min

DT = volume / flow = (16,000 ft^3) / (775 ft^3/min) = 20.6 min

APPENDIX I - ANSWERS TO EXERCISES (Chemical Dosing):

1. Determine the chlorinator setting (lbs/day) needed to treat a flow of 3 MGD with a chlorine dose of 4 mg/L.

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (3 MGD)(4 mg/L)(8.34 lbs/day)
= 100 lbs/day

2. Determine the chlorinator setting (lbs/day) if a flow of 3.8 MGD is to be treated with a chlorine dose of 2.7 mg/L.

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (3.8 MGD)(2.7 mg/L)(8.34 lbs/day)
= 86 lbs/day

3. A jar test indicates that the best dry alum dose is 12 mg/L. If a flow is 3.5 MGD, what is the desired alum feed rate?

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (3.5 MGD)(12 mg/L)(8.34 lbs/day)
= 350 lbs/day

4. The chlorine feed rate at a plant is 175 lbs/day. If the flow is 2,450,000 gpd, what is the dosage in mg/L?

Chemical Dose (mg/L) = Feed (lbs/day) / Flow (MGD) / (8.34 lbs/gal)
= (175 lbs/day) / (2.45 MGD) / (8.34 lbs/day)
= 8.6 mg/L

5. A total chlorine dosage of 12 mg/L is required to treat a particular water. If a flow 1.2 MGD and the hypochlorite has 65% available chlorine how many lbs/day of hypochlorite will be required?

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (1.2 MGD)(12 mg/L)(8.34 lbs/day)
= 120 lbs/day
= (120 lbs/day) / 0.65
= 185 lbs/day

6. A flow of 800,000 gpd requires a chlorine dose of 9 mg/L. If chlorinated lime (34% available chlorine) is to be used, how many lbs/day of chlorinated lime will be required?

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (0.8 MGD)(9 mg/L)(8.34 lbs/day)
= 60 lbs/day
= (60 lbs/day)/0.34
= 177 lbs/day

7. Determine the flow when 45 lbs of chlorine results in a chlorine dose of 1.7 mg/L.

Flow (MGD) = Feed (lbs/day) / Dose (mg/L) / (8.34 lbs/day)
= (45 lbs) / (1.7 mg/L) / (8.34 lbs/day)
= 3.2 MGD

APPENDIX I - ANSWERS TO EXERCISES (Chemical Dosing) CONTINUED:

8. A pipeline 10 inches in diameter and 900 ft long is to be treated with a chorine dose of 50 mg/L. How many lbs of chlorine will this require?

10 in x (1 ft/12 in) = 0.83 ft

Volume (MG) = 0.785 x D^2 x L x (7.48 gal/1 ft^3)
= 0.785(0.83 ft)^2(900 ft)(7.48 gal/1 ft^3)
= 3640 gal(1 MG/1,000,000 gal)
= 0.00364 MG

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (0.00364 MGD)(50 mg/L)(8.34 lbs/day)
= 1.5 lbs/day

9. The flow meter reading at 8 am on Wednesday was 18,762,102 gal and at 8 am on Thursday was 19,414,522 gal. If the chlorinator setting is 15 lbs for this 24 hour period, what is the chlorine dosage in mg/L?

Volume (MG) = 19,414,522 – 18,762,102 = 652,420 gal
= 652,420 gal(1 MG/1,000,000 gal)
= 0.652 MG

Chemical Dose (mgL) = Feed (lbs/day) / Flow (MGD) / (8.34 lbs/gal)
= (15 lbs/day) / (0.652 MGD) / (8.34 lbs/day)
= 2.8 mg/L

10. To disinfect an 8-inch diameter water main 400 feet long, an initial chlorine dose of 400 mg/L is expected to maintain a chlorine residual of over 300 mg/L during a three hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution is needed?

8 in x (1 ft/12 in) = 0.67 ft

Volume (gal) = (0.785)(D)^2(length)
= 0.785(0.67 ft)^2(400 ft)(7.48 gal/1 ft^3)
= 1054 gal(1 MG/1,000,000 gal)
= 0.001054 MGD

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (0.001054 MGD)(400 mg/L)(8.34 lbs/day)
= 3.5 lbs/day

= (3.5 lbs/day) / 0.0525
= 66.7 lbs/day

= 66.7 lbs X (1 gal/8.34 lbs)
= 8 gal

11. A container weighing 55 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 205 grams after 4 minutes. What is the dosage in lbs/day?

Feed (gr/min) = (205-55 grams) / (4 min)
= 37.5 g/min
(gr/day) = 37.5 X 1440
= 54,000 gr/day
(lbs/day) = 54,000 gr/day / 424 gr/lb
= **119 lbs/day**

APPENDIX J - ANSWERS TO EXERCISES (Chemical Demand):

1. What is the chlorine demand in mg/L, if the chlorine dose is 3.2 mg/L and the chlorine residual is 0.3 mg/L?

demand = dose – residual = 3.2 mg/L – 0.3 mg/L = 2.9 mg/L

2. What is the chlorine residual, if the chlorine demand is 1.8 mg/L and the chlorine dose is 10 mg/L?

residual = dose – demand = 10 mg/L – 1.8 mg/L = 8.2 mg/L

3. What is the chlorine dose, if the chlorine demand is 4.8 mg/L and the chlorine residual is 2 mg/L?

dose = demand + residual = 4.8 mg/L + 2 mg/L = 6.8 mg/L

4. The chlorine demand is 7 mg/L and the chlorine residual is 0.2 mg/L. What is the chlorine dose?

dose = demand + residual = 7 mg/L + 0.2 mg/L = 7.2 mg/L

5. The chlorine dose is 5 mg/L and the chlorine demand is 2.7 mg/L. What is the chlorine residual?

residual = dose – demand = 5 mg/L – 2.7 mg/L = 2.3 mg/L

6. The chlorine dose is 12 mg/L and the chlorine residual is 1.5 mg/L. What is the chlorine demand?

demand = dose – residual = 12 mg/L – 1.5 mg/L = 10.5 mg/L

7. What is the chlorine demand in mg/L, if the chlorine dose is 5.2 mg/L and the chlorine residual is 0.3 mg/L?

demand = dose – residual = 5.2 mg/L – 0.3 mg/L = 4.9 mg/L

8. If an operator feeds a chlorine dosage of 1.8 mg/L and the system has a chlorine demand of 1.3 mg/L, what would the final chlorine residual be?

residual = Dosage – Demand = 1.8 mg/L – 1.3 mg/L = 0.5 mg/L

9. What is the chlorine residual, if the chlorine demand is 2.3 mg/L and the chlorine dose is 3.4 mg/L?

residual = Dosage – Demand = 3.4 mg/L – 2.3 mg/L = 1.1 mg/L

10. What is the chlorine demand if the chlorine residual is 1.2 mg/L and 4.7 mg/L of chlorine has been added?

demand = dose – residual = 4.7 mg/L – 1.2 mg/L = 3.5 mg/L

APPENDIX K - ANSWERS TO EXERCISES (Fluoridation):

1. A plant uses 19 gallons of solution from its saturator in treating 360,000 gallons of water. What is the calculated dosage?

$$\text{Dosage (mg/L)} = \frac{\text{Solution fed (gal) x 18,000 mg/L}}{\text{Capacity (gpd)}}$$

$$= \frac{\text{19 gal x 18,000 mg/L}}{\text{360,000 gal}} = \frac{\text{342,000 mg/L}}{\text{360,000}} = \text{0.95 mg/L}$$

2. A plant uses 65 pounds of sodium fluorosilicate in treating 5.54 MG of water in one day. What is the calculated dosage?

$$\text{Dosage (mg/L)} = \frac{\text{Fluoride Feed Rate (lbs/day) X (Available Fluoride Ion) X (Chemical Purity)}}{\text{Capacity (MGD) X 8.34 lbs/gal}}$$

$$= \frac{\text{65 lbs/day x 0.607 x 0.98}}{\text{5.54 MGD x 8.34 lbs/gal}} = \frac{38.9}{46.2} = \text{0.84 mg/L}$$

3. A water plant produces 2,000 gpm and the city wants to add 1.1 mg/L of fluoride using sodium fluorosilicate, Na_2SiF_6. What is the feed rate in lbs/day?

$$\text{Fluoride Feed rate (lbs/day)} = \frac{\text{Dose (mg/L) x Capacity (MGD) x 8.34 lbs/gal}}{\text{(Available Fluoride Ion, AFI)(chemical purity, as decimal)}}$$

$$= \frac{\text{1.1 mg/L x 2000 gpm x (1 MGD/694.4 gpm) x 8.34 lbs/day}}{\text{(0.607)(0.98)}}$$

$$= \frac{26.42}{0.60} \text{ lbs/day} = \text{44 lbs/day}$$

4. A water plant produces 250,000 gpd and has a natural fluoride of 0.4 mg/L. If the plant were using sodium fluorde, what would the fluoride feed rate be to obtain a 1.0 mg/L in the water?

$$\text{Fluoride Feed rate (gpd)} = \frac{\text{Dose (mg/L) x Capacity (gpd)}}{\text{18,000 mg/L}}$$

$$= \frac{\text{(1.0 mg/L – 0.4 mg/L) x 250,000 gpd}}{\text{18,000 mg/L}} = \frac{\text{(0.6 mg/L)(250,000 gpd)}}{\text{18,000 mg/L}}$$

$$= \frac{\text{150,000 gpd}}{\text{18,000}} = \text{8.3 gpd}$$

APPENDIX K - ANSWERS TO EXERCISES (Fluoridation) CONTINUED:

5. You treat a volume of 2,035,000 gallons of water with 40 pounds of Fluorosilicic Acid during one day. What is the calculated dosage?

$$\text{Dosage (mg/L)} = \frac{\text{Fluoride Feed Rate (lbs/day) X (Available Fluoride Ion) X (Chemical Purity)}}{\text{Capacity (MGD) X 8.34 lbs/gal}}$$

$$= \frac{\text{40 lbs/day x 0.792 x 0.23}}{\text{2.035 MGD x 8.34 lbs/gal}}$$

= 0.43 mg/L

6. Calculate the dosage if a plant uses 40 gallons of solution from its saturator to treat 025 MG of water.

$$\text{Dosage (mg/L)} = \frac{\text{Solution fed (gal) x 18,000 mg/L}}{\text{Capacity (gpd)}}$$

$$= \frac{\text{40 gal x 18,000 mg/L}}{\text{250,000 gal}}$$

= 2.88 mg/L

7. What would the fluoride feed rate be to obtain a dose of 1.5 mg/L, if the plant uses sodium fluoride, produces 500,000 gpd, and has a natural fluoride content <0.1 mg/L?

$$\text{Fluoride Feed rate (gpd)} = \frac{\text{Dose (mg/L) x Capacity (gpd)}}{\text{18,000 mg/L}}$$

$$= \frac{\text{1.5 mg/L x 500,000 gpd}}{\text{18,000 mg/L}}$$

$$= \frac{\text{750,000 gpd}}{\text{18,000}}$$

= 41.67 gpd

8. A water plant wants to use sodium fluorosilicate to add 0.9 mg/L of fluoride to their water. If the plant produces 3,300 gpm, what is the feed rate in lbs/day?

$$\text{Fluoride Feed rate (lbs/day)} = \frac{\text{Dose (mg/L) x Capacity (MGD) x 8.34 lbs/gal}}{\text{(Available Fluoride Ion, AFI)(chemical purity, as decimal)}}$$

$$= \frac{\text{0.9 mg/L x 3,300 gpm x (1 MGD/694.4 gpm) x 8.34 lbs/day}}{\text{(0.607) x (0.985)}}$$

$$= \frac{35.67}{0.60} \text{ lbs/day}$$

= 59 lbs/day

APPENDIX L – ANSWERS TO EXERCISES (Potassium Permanganate):

1. A raw water analysis shows an iron level of 2.46 mg/L and a manganese level of 1.03 mg/L. What is the demand for potassium permanganate?

$KMnO_4$ Dose = 1(Iron Con.) + 2(Manganese Con.)
= 1(2.46) + 2(1.03)
= 4.52 mg/L

2. Your water system is recording iron concentrations of 1.82 mg/L and manganese concentrations of 0.68 mg/L in your raw water. What is the $KMnO_4$ demand?

$KMnO_4$ Dose = 1(Iron Con.) + 2(Manganese Con.)
= 1(1.82) + 2(0.68)
= 3.18 mg/L

3. A water system is reporting an iron concentration of 8.2 mg/gallon and a manganese concentration of 5.0 mg/gallon. What is the demand for potassium permanganate?

Iron mg/L = (8.2 mg/gal) / (3.785 gal/L) = 2.166 mg/L
Manganese mg/L = (5.0 mg/gal) / (3.785 gal/L) = 1.321 mg/L

$KMnO_4$ Dose = 1(Iron Con.) + 2(Manganese Con.)
= 1(2.166) + 2(1.321)
= 4.81 mg/L

4. Raw water measures manganese levels of 0.42 mg/L and total iron levels of 0.15 mg/L. How many pounds of potassium permanganate should be fed to treat 0.2 MG per day for only iron and manganese?

$KMnO_4$ Dose = 1(Iron Con.) + 2(Manganese Con.)
= 1(0.15) + 2(0.42)
= 0.99 mg/L

Total $KMnO_4$ Required = (0.99 mg/L) X (8.34) X (0.2 MG)
= 1.65 lbs

5. If raw water has a 0.36 mg/L iron concentration and a 1.27 mg/L manganese concentration. How many pounds of KMnO4 are needed to treat 100,000 gallons per day for only iron and manganese?

$KMnO_4$ Dose = 1(Iron Con.) + 2(Manganese Con.)
= 1(0.36) + 2(1.27)
= 2.9 mg/L

MG/g = 100,000 gal X (1 MG/1,000,000 gal) = 0.1 MG

Total $KMnO_4$ Required = (2.9 mg/L) X (8.34) X (0.1 MG)
= 2.42 lbs

APPENDIX M - ANSWERS TO MISC. SAMPLE PROBLEMS:

1. What is the area of the water surface in a tank that measures 25 feet wide and 32 feet long?

Area = Length x Width = 32 ft x 25 ft = **800 ft^2**

2. What is the area in square inches of a 10 inch ductile iron pipe?

Area = $0.785D^2$ = $0.785(10 \text{ in})^2$ = **78.5 in^2**

3. What is the circumference of a standpipe that has a radius of 22 feet a height of 200 feet?

Diameter = 2r = 2(22 ft) = 44 ft

Circumference = 3.14D = 3.14(44 ft) = **138.16 ft**

4. What is the volume in cubic feet of a tank that measures 50 feet long, 35 feet wide and is 12 feet deep?

Volume = Length x Width x Height = (50 ft)(35 ft)(12 ft)
= **21,000 ft^3**

5. What is the volume in gallons of a circular tank that measures 50 feet in diameter and has a sidewall depth of 18 feet?

Volume = $0.785D^2$ x Height x 7.48 gal/1 ft^3
= $(0.785)(50 \text{ ft})^2(18 \text{ ft})(7.48 \text{ gal}/1 \text{ ft}^3)$
= 264,231 gal

6. What is the detention time of a tank that measure 45 feet in diameter and has depth of 22 feet? The flow to the tank is 2300 gpm.

Volume = $0.785D^2$ x Height x 7.48 gal/1 ft^3
= $(0.785)(45 \text{ ft})^2(22 \text{ ft})(7.48 \text{ gal}/1 \text{ ft}^3)$
= 261,589 gal

Detention Time = Volume / Flow = 261,589 gal/2300 gpm = **114 min**

7. How many pounds of chlorine would it take to raise the residual of the above tank to 50 ppm?

Volume = $0.785D^2$ x Height x 7.48 gal/1 ft^3
= $(0.785)(45 \text{ ft})^2(22 \text{ ft})(7.48 \text{ gal}/1 \text{ ft}^3)$
= 261,589 gal x (1 MG/1,000,000 gal)
= 0.261589 MG

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (0.261589 MGD)(50 mg/L)(8.34 lbs/day)
= **109 lbs/day**

APPENDIX M - ANSWERS TO MISC. SAMPLE PROBLEMS CONTINUED:

8. Calcium hypochlorite is 70 percent available chlorine. How many pounds would be required to raise the residual of 400,000 gallons of water to 50 ppm?

Volume = 400,000 gal X (1 MG/1,000,000 gal)
= 0.40 MG

Chemical Feed (lbs/day) = Flow (MGD) X Dose (mg/L) X (8.34 lbs/gal)
= (0.40 MGD)(50 mg/L)(8.34 lbs/day)
= 166.8 lbs/day

$$\text{Pounds per day} = \frac{\text{pounds pure chemical}}{\text{percent purity, as decimal}} = \frac{166.8 \text{ lbs}}{0.70}$$

= **238 pounds**

9. Determine the flow in cubic feet per second if the velocity in a 12 inch pipe is 4 feet per second? (3.14 ftsec)

12 in x (1 ft/12 in) = 1 ft

Q = Area x velocity = 0.785 $(1 \text{ ft})^2$ x 4 ft/sec = **3.14 ft^3/sec**

10. Last month your system pumped 7,106,300 gallons of water into the distribution system. Your system was able to account for 5,264,800. What was your % unaccounted for water that month?

$$\text{Unaccounted \%} = \frac{\text{produced} - \text{sold}}{\text{produced}} \text{ X } 100 =$$

$$= \frac{7{,}106{,}300 - 5{,}264{,}800}{7{,}106{,}300} \text{ X } 100 = \mathbf{25.9\%}$$

11. Your water treatment plant currently treats water at a rate of 700 gpm. How many MGD is this?

$$\text{MGD} = \frac{700 \text{ gpm x } 1440 \text{ min/day}}{1{,}000{,}000} = \mathbf{1.008 \text{ MGD}}$$

12. Your clear well pump delivers 750 GPM to your main water storage tank. The demand for water for this tank is approximately six million gallons per week. How many hours will you need to run the pump per week to meet the demand?

$$\frac{\text{Hours}}{\text{Week}} = \frac{\text{min}}{750 \text{ gal}} \text{ x } \frac{6{,}000{,}000}{\text{week}} \text{ x } \frac{1 \text{ Hr}}{60 \text{ min}} = \mathbf{133.33 \text{ hours}}$$

APPENDIX M - ANSWERS TO MISC. SAMPLE PROBLEMS CONTINUED:

13. To accurately obtain a chlorine residual from your system, you are sampling from a customers tap. You would like to flush twice the volume of the service line before sampling. The service line is ¾" and approximately 200 feet from the main. How many gallons must you flush?

First a ¾" line is 0.0625 feet. = ¾ = 0.75 in = 0.75 in x 1 ft/12 in = 0.0625 ft

Volume = .785 x $(0.0625)^2$ x 200 x 7.48 = 4.6 gallons

2 x Volume = 2 x 4.6 gallons = **9.2 gallons**

14. You have replaced ¾ of the meters in your system. You have a total of 540 meters. How many will you need to complete the task of replacing all of the meters?

¾ = 75% = 0.75

Part = Percent x whole = (.75)(540) = 405

Whole – part = 540 - 405 = **135**

15. 77° F is the same temperature as:

C = 0.56 x (F – 32) = 0.56 x (77-32) = **25°C**

16. If chlorine costs $0.53/lb, what is the daily cost to chlorinate 7 MGD of water to an initial concentration of 2.3 mg/L?

lbs/day = 2.3 mg/L X 7 MGD X 8.34 lbs
= (134.27 lbs/day)($0.53)
= **$71.17/day**

17. How many gallons of sodium hypochlorite (12.5%) are required to disinfect an 3-inch water line 1500 feet long using the dosage of 50 mg/L?

3 in X (1 ft/12 in.) = .25 ft.

V = 0.785 X $(.25\ ft)^2$ X 1500 ft X 7.84 gal/ft^3
= (550.5 gal) / 1,000,000 MG/gal
= .000505 MG

lbs = [dose mg/L X flow MGD X 8.34] / (% as decimal)
= [50 mg/L X .000505 MGD X 8.34] / 0.125
= 1.7 lbs. X (1 gal/8.34)
= **0.202 gal**

18. If a hypochlorinator (treating well water) is set at a pumping rate of 10 gpd and uses an 18% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 160 GPM?

lbs = 10 gpd x 8.34 lb/gal = 83.4 lbs x 0.18 = 15.01 lbs

160 gpm x 1 MG/694.4 gpm = 0.23 MG

Dose, mg/L = lbs/day ÷ flow, MGD ÷ 8.34 lbs/gal
= 15.01 lbs/day ÷ 0.23 MGD ÷ 8.34 lbs/gal = **7.83 mg/L**

APPENDIX N - ANSWERS TO SAMPLE QUIZ:

Addition, Subtraction, Multiplication & Division

1. If a water distribution system is made up a 4,322 feet of 6-inch water line, 2,105 feet of 4-inch water line and 788 feet of 2-inch water line, how many feet of water line total is in the system?

4,322 ft + 2,105 ft + 788 ft = **7,215 ft**

2. The water level in a water storage reservoir drops an average of 3 feet per day. If the water level began at 57 feet, what is the water level after 6 days?

6 days X 3 ft = 18 ft/day

57 ft - 18 ft = **39 ft**

3. A water system serves 48 residential connections each of which use an average of 280 gallons per day. How many gallons total in the system are used each day?

48 customers X 280 gpd = **13,440 gpd**

4. Last year the water system used 96 gallons of chlorine solution. On average, how many gallons of chlorine solution were used each month?

96 gal/year X (12 month/1 yr) = **8 gal/month**

5. If 2 feet of head is lost per 1,700 feet of water line, how many feet of head are lost in a water line that is 13,600 feet long?

1700 ft / 2ft = 850

13,600 ft / 850 = **16 ft**

6. A water system bills at a rate of $0.65/1,000 gallons for the first 10,000 gallons; $0.40/1,000 gallons for the next 12,500 gallons; and $0.20/1,000 gallons for everything over 22,500 gallons. If a customer uses 30,000 gallons, how much is the water bill?

30.000 gallons
<u>-10,000 gallons</u> X ($0.65/1000 gallons) = $6.50
20,000 gallons
<u>-12,500 gallons</u> X ($0.40/1000 gallons) = $5.00
7,500 gallons X ($0.20/1000 gallons) = <u>$1.50</u>
$13.00

Decimals, Fractions & Percentages

7. Convert 0.92 to a percentage.

0.92 X 100% = **92%**

8. A water system has a total of 425 connections, 16% of which are commercial. How many commercial connections are there?

425 connections X 16/100 = **68 connections**

9. A water system diverts 1/3 of its total water supply to a RO treatment unit which reduces the total dissolved solids in the water. If the total water supply for the system is 870,000 gallons per day, how many gallons per day are being treated?

870,000 gal X 1/3 = **290,000 gal**

10. During a typical day, 42% of the total storage capacity in a water system is used. If the system has a storage capacity of 350,000 gallons, how many gallons are remaining at the end of each d ?

100% - 42% = 58% = 0.58

(350,000 gal) X (0.58) = **203,000 gal** (remaining each day)

11. You have been asked to report the unaccounted for water in your system. Your plant produced 7.23 MG last month, and the meter readings indicate 5.84 MG was billed. The flushing program used 30,000 gallons, and the local fire department used 20,000. What is your percentage of unaccounted water?

5.84 + .03 + .02 = 5.89 MG

7.23 – 5.89 = 1.34 MG

(1.34/7.23) X 100= 18.5%

Unit Conversions

12. Convert 2,000 gallons into cubic feet.

2,000 gal X (1 ft^3/7.48 gal) = **267 ft^3**

13. The cross sectional area of a pipe is 200 square inches. What is the cross sectional area of that pie in square feet?

200 in^2 X (1 ft^2/144 in^2) = **1.4 ft^2**

14. The flow rate in a pipe is measure at 500 gallons/minute. Convert that flow rate into cubic feet/minute.

500 gal/min X (1 ft^3/7.48 gal) = **67 ft^3/min**

15. A storage tank is filling at a rate of 10.7 feet per hour. What is the fill rate in feet per minute?

10.7 ft/hr X (1 hr/60 min) = **0.2 ft/min**

Area Calculations

16. If a water pipe is 10 inches in diameter, what is the cross sectional area of that pipe in square inches?

Area = $0.785D^2 = 0.785(10\text{ in})^2 =$ **78.5 in^2**

17. A tank is 20 feet tall and 12 feet in diameter. What is the area of the top of the tank in square feet?

Area = $0.785D^2 = 0.785(12\text{ ft})^2 =$ **113 ft^2**

18. If a water pipe is 18 inches in diameter and 2 miles long, what is the cross sectional area of that pipe in square feet?

18 in X (1 ft/12 in) = 1.5 ft

Area = $0.785D^2 = 0.785(1.5\text{ ft})^2 =$ **1.8 ft^2**

Volume Calculations

19. If a water reservoir is 200 feet long, 275 feet wide and 12 feet deep, what is the volume of water it can hold in cubic feet?

Volume = L x W x H = 200 ft x 275 ft x 12 ft
= **$660{,}000\text{ ft}^3$**

20. If a water tank is 50 feet in diameter and 30 feet tall, long, what is the volume of water it can hold in gallons?

Volume = $0.785D^2$ x Height x (7.48 gal/1 ft^3)
= $0.785(50\text{ ft})^2(30\text{ft})$ (7.48 gal/1 ft^3)
= **440,385 gal**

21. If a water tank has a diameter of 20 feet and is 85 feet tall, how much water in gallons can the tank hold?

Volume = $0.785D^2H$ x (7.48 gal/1 ft^3)
= $0.785(20\text{ ft})^2(85\text{ ft})$ (7.48 gal/1 ft^3)
= **199,641 gal**

22. If a water pipe is 1.5 feet in diameter and 6850 feet long, what is the volume of the pipe in gallons?

Volume = $0.785D^2H$ x (7.48 gal/1 ft^3)
= $0.785(1.5\text{ ft})^2(6850\text{ ft})$ (7.48 gal/1 ft^3)
= **90,499 gal**

APPENDIX N - ANSWERS TO SAMPLE QUIZ CONTINUED:

23. A water tank is designed to hold enough water to a water system for 2 days without being refilled. If the water system has 318 connections and each connection uses 115 gallons per day, how many gallons should the tank hold in gallons?

318 connections x 115 gpd x 2 days = **73,140 gallons**

Flow Rate Calculations

24. If a water plant treats 1.6 million gallons per day, what is the flow rate out if the plant in gallons/minute?

1.6 MGD x (694.4 gpm/1 MGD) = **1111 gpm**

25. Water in a 10-inch pipe is moving at 2.5 ft/sec. What is the flow rate in the pipe in gal/min?

10 in x (1 ft/12 in) = 0.83 ft
$Q = A \times v = (0.785)(0.83\ \text{ft})^2(2.5\ \text{ft/sec}) = 1.35\ \text{ft}^3\text{/sec}$
$1.35\ \text{ft}^3\text{/sec} \times (7.48\ \text{gal}/1\ \text{ft}^3) \times (60\ \text{sec}/1\ \text{min}) =$ **606 gpm**

Dosage Calculations

26. A well which supplies a water system has a constant chlorine demand of 2.3 mg/L. If the operator wants to maintain a residual of 1.1 mg/L, what many mg/L should the operator dose with?

Dose = Demand + Residual
= 2.3 mg/L + 1.1 mg/L
= **3.4 mg/L**

27. A rural water system requires 30 lbs/day of chlorine to disinfect it's water supply. If the operator uses a 15% sodium hypochlorite solution, how many pounds per day will he need to use?

$\frac{30\ \text{lbs/day}}{0.15}$ = **200 lbs/day**

28. A water plant processes 903 gal/min. If the chlorine dose added to the water is 2.4 mg/L, how many pounds of chlorine are used each day?

903 gpm x (1 MGD/694.4 gpm) = 1.3 MGD

Feed (lbs/day) = Dose (mg/L) X Flow (MG) X 8.34lb/gal
= 2.4 mg/L X 1.3 MG X 8.34 lb/gal = **26 lbs/day**

APPENDIX N - ANSWERS TO SAMPLE QUIZ CONTINUED:

29. A water plant processes 0.87 MGD If the chlorine dose added to the water is 3.0 mg/L, how many pounds of a 12% sodium hypochlorite solution are used each day?

Feed (lbs/day) = Dose (mg/L) X Flow (MG) X 8.34 lb/gal
= 3.0 mg/L x 0.87 MG x 8.34 = 22 lbs/day

$= \frac{22 \text{ lbs/day}}{0.12}$ = **183 lbs/day**

30. A new installed 12-inch diameter line that is 4050 feet long needs to be disinfected. The operator fills that pipe with water and adds 10 pounds of 5% sodium hypochlorite solution to disinfect the line. What is the chlorine dose in the pipe in mg/L?

12 in x (1 ft/12 in) = 1 ft

Volume = $0.785D^2L$ x (7.48 gal/1 ft^3) x (1MG/1,000,000 gal)
= 0.785 $(1 \text{ ft})^2$(4050)(7.48 gal/ft^3) 1MG/1,000,000 gal)
= 0.024 MG

Available Chlorine = lbs x %(as decimal) = 10 x 0.05 = 0.5 lbs

Dose (mg/L) = Feed (lbs/day) / Flow (MGD) / (8.34 lbs/gal)
= (0.5 lbs/day) ÷ (0.024 MGD) ÷(8.34 lbs/gal)
= **2.5 mg/L**

APPENDIX O - ANSWERS TO: CLASS I MATH EXAM PREP – IN CLASS:

1. A water sample has the following results:
   Bromodichloromethane 0.018 mg/L,
   Chloroform 0.038 mg/L,
   Bromoform 0.002 mg/L,
   Dibromochloromethane 0.006mg/L.

   (0.018 + 0.038 + 0.002 + 0.006) mg/L = **0.064 mg/L**

2. What is the chlorine demand if the water has a chlorine dose of 2.5 mg/L and the residual is 0.2 mg/L?

   Demand, mg/L = Dose, mg/L – Residual, mg/L = 2.5 mg/L – 0.2 mg/L = **2.3 mg/L**

3. Calculate drawdown, in feet, using the following data. The water level in a well is 21 feet below the ground surface when the pump is not in operation. The water level is 37 feet below the ground surface when the pump is in operation.

   Drawdown, ft = pumping level, ft – static level, ft = (37 - 21) ft = **16 ft**

4. A water system bills at a rate of $0.70/1,000 gallons for the first 10,000 gallons; $0.55/1,000 gallons for the next 15,000 gallons; and $0.35/1,000 gallons for all over 25,000 gallons. If a customer uses 37,000 gallons, how much is the water bill?

37,000 gallons		
-10,000 gallons	x ($0.70/1000 gallons)	= $7.00
27,000 gallons		
-15,000 gallons	x ($0.55/1000 gallons)	= $8.25
12,000 gallons	x ($0.35/1000 gallons)	= $4.20
		$19.45

5. What is the average fluoride reading over the past week: 0.85 mg/L, 0.72 mg/L, 0.81 mg/L, 1.19 mg/L, 0.99 mg/L, 0.71 mg/L?

   $$\text{Average} = \frac{\text{Sum of Numbers}}{\text{Total Numbers}}$$

   $$= \frac{0.85 + 0.72 + 0.81 + 1.19 + 0.99 + 0.71\ (\text{mg/L})}{6} = \frac{5.27\ \text{mg/L}}{6} = \mathbf{0.88\ mg/L}$$

6. What is the 90^{th} percentile for lead content? The analytical results of the lead content of your water supply show the following results:

   0.007 mg/L, 0.016 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L

   90^{th} Percentile = 5 x 0.9 = 4.5

   $$= \frac{(\#5+\#4)}{2} = \frac{(0.018 + 0.016)\ \text{mg/L}}{2} = \frac{0.034\ \text{mg/L}}{2} = \mathbf{0.017\ mg/L}$$

7. The beginning reading of a master meter reads 8,324,844 and seven days later this same meter reads 27,017,998. What is the total gallons pumped and what is the daily average?

   Total gallons = (27,017,998-8,324,844) gal = **18,693,154 gal**

   $$\text{Average gallons} = \frac{18{,}693{,}154 \text{ gal}}{7 \text{ days}} = \mathbf{2{,}670{,}450.57 \text{ gal/day}}$$

8. Last month your Water System pumped 5,106,300 gallons of water into the distribution system. Your system was able to account for 3,264,800 gallons. What was your unaccounted for % of water for this month?

   $$\text{Unaccounted, \%} = \frac{(\text{Pumped, gal} - \text{Accounted, gal})}{\text{Pumped, gal}} \times 100\% =$$

   $$= \frac{(5{,}106{,}300 - 3{,}264{,}800) \text{ gal}}{5{,}106{,}300 \text{ gal}} \times 100\% = \frac{1{,}841{,}500 \times 100\%}{5{,}106{,}300} = \mathbf{36.06\%}$$

9. During a 30 day period a booster station pumped 23,720 gallons of water to an isolated pressure zone. During the same period the customers of the zone were billed for a total of 15,630 gallons of water used. Also during this period the high service pumps produced 5,200,000 gallons into the distribution system. What is the water loss percentage for the pressure zone?

   $$\text{Unaccounted, \%} = \frac{(\text{Pumped, gal} - \text{Accounted, gal})}{\text{Pumped, gal}} \times 100\% =$$

   $$= \frac{(23{,}720 - 15{,}630)\text{gal}}{23{,}720 \text{ gal}} \times 100\% = \frac{8{,}090 \times 100\%}{23{,}720} = \mathbf{34.11\%}$$

10. Your system is preparing to apply for a rate increase and the PSC is asking about your “unaccounted for water” for the month of July. Your plant produced 5.18 MG in July and the meter readings indicate 4.68 MG was billed. You have been informed that the fire department hauled 50,000 gallons to farmers and the hydrant flushing program used 40,000 gallons. What would you report as the unaccounted for water?

    Accounted, MG = 4.68 + 0.05 + 0.04 = 4.77 MG

    $$\text{Unaccounted, \%} = \frac{(\text{Pumped, gal} - \text{Accounted, gal})}{\text{Pumped, gal}} \times 100\% =$$

    $$= \frac{(5.18 - 4.77) \text{ MG}}{5.18 \text{ MG}} \times 100\% = \frac{0.41 \times 100\%}{5.18} = \mathbf{7.92\%}$$

11. In 25 pounds of 70 percent calcium hypochlorite there are:

    Chlorine, lbs = Hypochlorite, lbs x % Purity, as decimal
    = (25 lbs.) x (0.70) **= 17.5 lbs**

12. A distribution booster station operates 14 hours per day. The system requires that the water must be re-chlorinated and expects to use 16 lbs of Cl_2 per day. The booster station pumps 500 gpm. The operator should set the chlorine feed rate at:

    $\frac{\text{Total lbs}}{\text{Run, hrs}} = \frac{\text{16 lbs}}{\text{14 hr}} =$ **1.14 lbs per hour**

13. Convert 70°F is what in Celsius?

    C = 0.56 x (F-32) = 0.56 x (70°-32°) = 0.56 x 38° = **21.28°**

14. A temperature measured 25°C is what in Fahrenheit?

    F = (1.8 x C°) + 32 = (1.8 x 25°) + 32 = 45° + 32 = **77°**

15. A 3.27% chlorine solution is what concentration in mg/L?

    3.27 % x $\frac{\text{10,000 mg/L}}{1\%}$ = **32,700 mg/L**

16. Convert 10.8 grains per gallon to mg/L of hardness:

    10.8 gpg x <u>17.12 mg/L</u>

17. The elevation of water in the tank is at 1,500 feet, the elevation of the pump is 600 feet. What is the gauge pressure at the pump?

    900 ft x $\frac{\text{0.433 psi}}{\text{1 ft}}$ = **389.7 psi**

18. Two columns of water are filled completely at sea level to a height of 78 feet. Column A is 0.5 inches in diameter. Column B is 5 inches in diameter. What will two pressure gauges, one attached to the bottom of each column read?

    78 ft x $\frac{\text{0.433 psi}}{\text{1 ft}}$ **= 33.77 psi**

19. A water treatment plant used 62 chlorine cylinders during one year of operation. The average withdrawal from each cylinder was 142 lbs. What was the total number of pounds of chlorine used for the year?

    62 cylinders/year x 142 lbs/cylinder = **8,804 lbs/year**

20. A chemical pump is calibrated by timing to deliver 450 milliliter in 15 seconds. How much chemical is being added in gallons per minute?

$$\frac{450\text{ mL}}{15\text{ sec}} \times \frac{60\text{ sec}}{1\text{min}} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{1\text{ gal}}{3.785\text{ L}} = \mathbf{0.48\ gal/min}$$

21. A leak of one (1) pint per minute is discovered. How many gallons is this per year.

$$\frac{1\text{ pint}}{1\text{ min}} \times \frac{1440\text{ min}}{1\text{ day}} \times \frac{365\text{ days}}{1\text{ yr}} \times \frac{1\text{ gal}}{8\text{ pints}} = \mathbf{65{,}700\ gal/yr}$$

22. A container weighing 45 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 152 grams after 2 minutes. What is the dosage in lbs/day?

$$\text{Dosage, gr/min} = \frac{(152 - 45\text{ gr})}{2\text{ min}} = \frac{107\text{ gr}}{2\text{ min}} = 53.5\text{ gr/min}$$

$$\text{Dosage, lbs/day} = 53.5\text{ gr/min} \times \frac{1440\text{min}}{1\text{ day}} \times \frac{1\text{ lb}}{454\text{ gr}} = \mathbf{169.69\ lbs/day}$$

23. If a 25 foot tall tank with a 70 foot diameter contains 15 feet of water, calculate the volume of water in gallons.

Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
= 0.785 x 70 ft x 70 ft x 15 ft x 7.48 gal/ft^3 = **431,577.3 gal**

24. Your utility is laying 7,000 feet of 12 inch main to a remote area of your distribution system. Average flow to this area is expected to be 0.015 MGD. What will be the average detention time (in days) for water in 12 inch main?

Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
= 0.785 x 1 ft x 1 ft x 7,000 ft x (7.48 gal/ft^3) = 41,102.6 gal

$$\text{DT, days} = \frac{41{,}102.6\text{ gallons}}{15{,}000\text{ gpd}} = \mathbf{2.74\ days}$$

25. Find the detention time in hours in a tank that measures 70 ft long by 55 ft wide and 25 ft deep with a flow to the tank of 1,500 gpm.

Volume = L, ft x W, ft x H, ft x 7.48 gal/ft^3
= 70 ft x 55 ft x 25 ft x 7.48 gal/ft^3 = 719,950 gal

$$\text{DT, hr} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{719{,}950\text{ gal}}{1{,}500\text{ gpm}} = 480\text{ min} \times \frac{1\text{ hr}}{60\text{ min}} = \mathbf{8\ hr}$$

26. A clearwell is 10 ft deep, 15 ft wide, and 40 feet long. If the flow through the clearwell is 0.40 MGD, what is the detention time in hours?

    Vol, gal = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    = 40 ft x 10 ft x 15 ft x 7.48 gal/ft^3 = 44,880 gal

    $$Q, gpm = 0.40\ MGD \times \frac{694.4\ gpm}{1\ MGD} = 277.76\ gpm$$

    $$DT, hours = \frac{V\ (gal)}{Q\ (gpm)} = \frac{44{,}880\ gal}{277.76\ gpm} = 161.57\ min \times \frac{1\ hr}{60\ min} = \mathbf{2.69\ hr}$$

27. How many hours would it take to use the water in a 250,000 ft. 8 inch pipe with an outflow of 1,500 gpm in an inflow of 500 gpm?

    8 in x (1 ft/12 in) = 0.67 ft

    Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
    = 0.785 x 0.67 ft x 0.67 ft x 250,000 ft x 7.48 gal/ft^3 = 658,962.76 gal

    $$DT, hours = \frac{Vol, gal}{flow, gpm} = \frac{658{,}962.76\ gal}{(1{,}500 - 500)\ gpm} = \frac{658{,}962.76\ gal}{1{,}000\ gpm} = 658.96\ min \times \frac{1\ hr}{60\ min} = \mathbf{10.98\ hr}$$

28. What amount of 100% chlorine is required to treat 0.20 million gallons of water to provide a 0.9 mg/L dose?

    Feed, lbs = Dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 0.9 mg/L x 0.2 MG x 8.34 lbs/gal = **1.5 lbs**

29. How many pounds of chlorine gas are required to treat 200 gpm of water to provide a 1.2 mg/L residual?

    $$200\ gpm \times \frac{1\ MGD}{694.4\ gpm} = 0.29\ MGD$$

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 1.2 mg/L x 0.29 MGD x 8.34 lbs/gal= **2.90 lbs**

30. A chlorinator is set to feed 10 pounds of chlorine in 24 hours to a flow of 0.5 MGD. Find the chlorine dose in mg/L.

    Dose, mg/L = feed (lbs/day)÷flow (MGD)÷8.34 lbs/gal =
    Dose, mg/L = 10 lbs ÷ 0.5 MGD ÷8.34 lbs/gal = **2.4 lbs/day**

31. Examination of the raw water shows manganese levels of 0.4 mg/L and total iron levels of 0.3 mg/L. How many pounds of potassium permanganate should be fed to treat 200,000 gallons per day for only iron and manganese?

    Gallons = 200,000 gallons/1MG = 0.2 MG

    Total Permanganate Demand = 1 x (Fe conc, mg/L) + 2 x (Mn conc, mg/L)
    =(1x 0.3 mg/L) + (2 x 0.4 mg/L) = 0.3 mg/L + 0.8 mg/L = 1.1 mg/L

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 1.1 mg/L X 0.20 MG X 8.34 lbs/gal = **1.83 lbs**

32. If chlorine costs $0.47/lb, what is the daily cost to chlorinate 2.5 MGD of water to an initial concentration of 1.6 mg/L?

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 1.6 mg/L x 2.5 MGD x 8.34 lbs/gal = 33.36 lbs/day
    = 33.36 lbs/day x $0.47/lb = **$15.68/day**

33. A rectangular reservoir 100 ft x 50 ft x 15 ft is filled with water. How many pounds of alum must be added in order to produce a dosage of 50 mg/L?

    Vol, gal = L, ft x W, ft x H, ft x 7.48 gal/ft^3

    $$= 100 \text{ ft} \times 50 \text{ ft} \times 15 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 561{,}000 \text{ gal} \times \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} = 0.56 \text{ MG}$$

    Feed, lbs/day = Dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 50 mg/L x 0.56 MG x 8.34 lbs/gal **= 233.52**

34. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line 2,000 feet long using dosage of 50 mg/L chlorine?

    6 in x 1ft/12 in = 0.5 ft

    Volume = 0.785 x $(D, ft)^2$ x (L, ft) x 7.48 gal/ft^3

    $$= 0.785 \times 0.5 \text{ ft} \times 0.5 \text{ ft} \times 2{,}000 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 2{,}935.9 \text{ gal} \times \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} = 0.029 \text{ MG}$$

    $$\text{Feed, lbs/day} = \frac{\text{Dose, mg/L x flow, MGD x 8.34 lbs/gal}}{\text{(\%, as decimal)}}$$

    $$= \frac{50 \text{ mg/L} \times 0.0029 \text{ MGD} \times 8.34 \text{ gal/ft}^3}{0.125} = \frac{1.21 \text{ lbs}}{0.125} = 9.68 \text{ lbs} \times \frac{1 \text{ gal}}{8.34 \text{ lbs}} = \mathbf{1.16 \text{ gal}}$$

35. Water from a well is being treated by hypochlorinator. If the hypochlorinator is set at a pumping rate of 6 gpd and uses a 12% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 180 GPM?

$$Q = 180 \text{ gpm} \times \frac{1 \text{ MGD}}{694.4 \text{ gpm}} = 0.26 \text{ MGD}$$

$$\text{Feed, lbs/day} = 6 \text{ gpd} \times \frac{8.34 \text{ lbs}}{1 \text{ gal}} = 50.04 \text{ lbs/day}$$

Dose, mg/L = Feed (lbs/day) ÷ flow (MGD) ÷ 8.34 lbs/gal
= 50.04 lbs/day ÷ 0.26 MGD ÷ 8.34 lbs/gal = 23.07 mg/L

Dose, mg/L @ 12% solution = 23.07 mg/L x 0.12 = **2.77 mg/L**

36. A water plant uses 20 gallons of sodium fluoride solution in treating 0.45 MGD of water. Natural fluoride ion is 0.25 mg/L. What is the calculated dosage?

$$\text{Capacity, gpd} = 0.45 \text{ MGD} \times \frac{1{,}000{,}000 \text{ gal}}{1 \text{ MG}} = 450{,}000 \text{ gpd}$$

$$\text{Dose, mg/L} = \frac{\text{Solution Fed,gal} \times 18{,}000 \text{ mg/L}}{\text{Capacity, gdp}}$$

$$= \frac{20 \text{ gal} \times 18{,}000 \text{ mg/L}}{450{,}000 \text{ gpd}} = \frac{360{,}000 \text{ mg/L}}{450{,}000} = \mathbf{0.8 \text{ mg/L}}$$

37. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 200,000 gallons of water. The raw water has a natural fluoride content of 0.2 mg/L and the desired fluoride in the finished water is 1.2 mg/L. How many gallons of feed solution is needed?

$$\text{Fluoride Feed Rate, gpd} = \frac{\text{Dose, mg/L} \times \text{Capacity, gpd}}{18{,}000 \text{ mg/L}}$$

$$= \frac{1.0 \text{ mg/L} \times 200{,}000 \text{ gallons}}{18{,}000 \text{ mg/L}} = \frac{200{,}000 \text{ gal}}{18{,}000} = \mathbf{11.11 \text{ gallons}}$$

38. A diaphragm pump feeds a polyphosphate to the clearwell to treat for iron and manganese. At 100% the pump will put out 150 mL per min. The operator must treat a plant flow of 0.50 MGD with 2.5 mg/L of polyphosphate. The polyphosphate weighs approximately 12 lbs/gallon. What is the pump setting?

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    2.5 mg/L X 0.5 MGD X 8.34 lbs/gal = 10.43 lbs

    $$\text{Vol, mL/min} = \frac{10.43\text{ lbs}}{\text{day}} \times \frac{1\text{gal}}{12\text{ lbs}} \times \frac{3785\text{ mL}}{1\text{ gal}} \times \frac{1\text{ day}}{1440\text{ min}} = 2.28\text{ mL}$$

    $$\frac{X\ \%}{2.28\text{ mL}} = \frac{100\%}{150\text{ mL}}$$

    $$X = \frac{(100\%)(2.28\text{ mL})}{150} = \frac{228\ \%}{150} = \mathbf{1.52\%}$$

39. The average chlorine residual entering a booster station is 0.3 mg/L. Using a gas chlorine feed system on site, the operator must boost the chlorine to a residual of 2.2 mg/L. The booster pump rated at 0.25 MGD runs 16 hours per day. How many pounds of Cl_2 will be fed per day?

    Volume Treated = 16 hours x 1 day/(24 hours) X 0.25 MGD = 0.17 MG

    Dosage Required = 2.2 – 0.3 = 1.9 mg/L

    Feed (lbs/day) = Dose (mg/L) x flow (MGD) x 8.34 lbs/gal =
    = 1.9 mg/L x 0.17 MGD x 8.34 lbs/gal = **2.69 lbs**

APPENDIX P - ANSWERS TO: CLASS I MATH EXAM PREP – HOMEWORK

1. A water sample has the following results:
   Bromodichloromethane 0.025 mg/L,
   Chloroform 0.045 mg/L,
   Bromoform 0.002 mg/L,
   Dibromochloromethane 0.006mg/L.

   (0.025 + 0.045 + 0.002 + 0.006) mg/L = **0.078 mg/L**

2. What is the chlorine demand if the water has a chlorine dose of 2.3 mg/L and the residual is 0.7 mg/L?

   Demand, mg/L = Dose, mg/L – Residual, mg/L = 2.3 mg/L – 0.7 mg/L = **1.6 mg/L**

3. Calculate drawdown, in feet, using the following data. The water level in a well is 21 feet below the ground surface when the pump is not in operation. The water level is 58 feet below the ground surface when the pump is in operation.

   Drawdown, ft = pumping level, ft – static level, ft = (58 - 21) ft = **37 ft**

4. A water system bills at a rate of $0.80/1,000 gallons for the first 10,000 gallons; $0.45/1,000 gallons for the next 15,000 gallons; and $0.30/1,000 gallons for all over 25,000 gallons. If a customer uses 36,000 gallons, how much is the water bill?

36,000 gallons		
-10,000 gallons	x ($0.80/1000 gallons)	= $8.00
26,000 gallons		
-15,000 gallons	x ($0.45/1000 gallons)	= $6.75
11,000 gallons	x ($0.30/1000 gallons)	= $3.30
		$18.05

5. What is the average fluoride reading over the past week: 0.85 mg/L, 0.72 mg/L, 0.84 mg/L, 1.09 mg/L, 0.92 mg/L, 0.51 mg/L?

$$\text{Average} = \frac{\text{Sum of Numbers}}{\text{Total Number}}$$

$$= \frac{(0.85 + 0.72 + 0.84 + 1.09 + 0.92 + 0.51)\ \text{mg/L}}{6} = \frac{4.93\ \text{mg/L}}{6} = \mathbf{0.82\ mg/L}$$

6. What is the 90^{th} percentile for lead content? The analytical results of the lead content of your water supply show the following results:

   0.007 mg/L, 0.016 mg/L, 0.021 mg/L, <0.002 mg/L and 0.010 mg/L

   90^{th} Percentile = 5 x 0.9 = 4.5

$$= \frac{(\#5+\#4)}{2} = \frac{(0.021 + 0.016)\ \text{mg/L}}{2} = \frac{0.037\ \text{mg/L}}{2} = 0.0185\ \text{mg/L}$$

7. The beginning reading of a master meter reads 6,324,844 and seven days later this same meter reads 29,017,998. What is the total gallons pumped and what is the daily average?

   Total gallons = (29,017,998 - 6,324,844) gal = **22,693,154 gal**

   $$\text{Average gallons} = \frac{22{,}693{,}154 \text{ gal}}{7 \text{ days}} = \mathbf{3{,}241{,}879.14 \text{ gal/day}}$$

8. Last month your Water System pumped 7,106,300 gallons of water into the distribution system. Your system was able to account for 5,764,800 gallons. What was your unaccounted for % of water for this month?

   $$\text{Unaccounted, \%} = \frac{(\text{Pumped} - \text{Accounted}) \text{ gal}}{\text{Pumped, gal}} \times 100\% =$$

   $$= \frac{(7{,}106{,}300 - 5{,}764{,}800) \text{ gal}}{7{,}106{,}300 \text{ gal}} \times 100\% = \frac{1{,}341{,}500 \times 100\%}{7{,}106{,}300} = \mathbf{18.88\%}$$

9. During a 30 day period a booster station pumped 22,625 gallons of water to an isolated pressure zone. During the same period the customers of the zone were billed for a total of 18,640 gallons of water used. Also during this period the high service pumps produced 5,200,000 gallons into the distribution system. What is the water loss percentage for the pressure zone?

   $$\text{Unaccounted, \%} = \frac{(\text{Pumped} - \text{Accounted}) \text{ gal}}{\text{Pumped, gal}} \times 100\% =$$

   $$= \frac{(22{,}625 - 18{,}640) \text{ gal}}{22{,}625 \text{ gal}} \times 100\% = \frac{3{,}985 \times 100\%}{22{,}625} = \mathbf{17.61\%}$$

10. Your system is preparing to apply for a rate increase and the PSC is asking about your "unaccounted for water" for the month of July. Your plant produced 5.18 MG in July and the meter readings indicate 4.48 MG was billed. You have been informed that the fire department hauled 50,000 gallons to farmers and the hydrant flushing program used 40,000 gallons. What would you report as the unaccounted for water?

    Accounted, MG = 4.48 MG + 0.05 MG + 0.04 MG = 4.57 MG

    $$\text{Unaccounted, \%} = \frac{(\text{Pumped, MG} - \text{Accounted, MG})}{\text{Pumped, MG}} \times 100\% =$$

    $$= \frac{(5.18 - 4.57) \text{ MG}}{5.18 \text{ MG}} \times 100\% = \frac{0.61 \times 100\%}{5.18} = \mathbf{11.78\%}$$

11. In 25 pounds of 65 percent calcium hypochlorite there are:

    Chlorine, lbs = Hypochlorite, lbs x % Purity, as decimal
    = 25 lbs x 0.65 = **16.25 lbs**

12. A distribution booster station operates 14 hours per day. The system requires that the water must be re-chlorinated and expects to use 20 lbs of Cl_2 per day. The booster station pumps 500 gpm. The operator should set the chlorine feed rate at:

    $\frac{\text{Total, lbs}}{\text{Run, hrs}} = \frac{20 \text{ lbs}}{14 \text{ hr}} = \mathbf{1.43 \text{ lbs/hr}}$

13. Convert 72°F is what in Celsius?

    C = 0.56 x (F-32) = 0.56 x (72°-32°) = 0.56 x 40° = **22.4°**

14. A temperature measured 29°C is what in Fahrenheit?

    F = (1.8 x C°) + 32 = (1.8 x 29°) + 32 = 52.2° + 32 = **84.2°**

15. A 4.75 chlorine solution is what concentration in mg/L?

    $4.75\ \% \times \frac{10{,}000 \text{ mg/L}}{1\%} = 4\mathbf{7{,}500 \text{ mg/L}}$

16. Convert 10.8 grains per gallon to mg/L of hardness:

    $14.8 \text{ gpg} \times \frac{17.12 \text{ mg/L}}{1 \text{ gpg}} = \mathbf{253.38 \text{ mg/L}}$

17. The elevation of water in the tank is at 1,500 feet, the elevation of the pump is 650 feet. What is the gauge pressure at the pump?

    $850 \text{ ft} \times \frac{0.433 \text{ psi}}{1 \text{ ft}} = \mathbf{368.05 \text{ psi}}$

18. Two columns of water are filled completely at sea level to a height of 72 feet. Column A is 0.5 inches in diameter. Column B is 5 inches in diameter. What will two pressure gauges, one attached to the bottom of each column read?

    $72 \text{ ft} \times \frac{0.433\text{psi}}{1\text{ft}} \mathbf{= 31.18 \text{ psi}}$

19. A water treatment plant used 62 chlorine cylinders during one year of operation. The average withdrawal from each cylinder was 146 lbs. What was the total number of pounds of chlorine used for the year?

    62 cylinders/year x 146 lbs/cylinder = **9,052 lbs/year**

20. A chemical pump is calibrated by timing to deliver 550 milliliter in 15 seconds. How much chemical is being added in gallons per minute?

    $\frac{550 \text{ mL}}{15 \text{ sec}} \times \frac{60 \text{ sec}}{1\text{min}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ gal}}{3.785 \text{ L}} = \mathbf{0.58 \text{ gal/min}}$

21. A leak of one (1) pint per minute is discovered. How many gallons is this per year.

$$\frac{1 \text{ pint} \times 1440 \text{ min} \times 365 \text{ days} \times 1 \text{ gal}}{1 \text{ min} \times 1 \text{ day} \times 1 \text{ yr} \times 8 \text{ pints}} = \mathbf{65{,}700 \text{ gal/yr}}$$

22. A container weighing 45 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 185 grams after 2 minutes. What is the dosage in lbs/day?

$$\text{Dosage, gr/min} = \frac{(185 - 45 \text{ gr})}{2 \text{ min}} = \frac{140 \text{ gr}}{2 \text{ min}} = 70 \text{ gr/min}$$

$$\text{Dosage, lbs/day} = 70 \text{ gr/min} \times \frac{1440 \text{min}}{1 \text{ day}} \times \frac{1 \text{ lb}}{454 \text{ gr}} = \mathbf{222.03 \text{ lbs/day}}$$

23. If a 25 foot tall tank with a 70 foot diameter contains 21 feet of water, calculate the volume of water in gallons.

Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
= 0.785 x 70 ft x 70 ft x 21 ft x 7.48 gal/ft^3 = **604,208.22 gal**

24. Your utility is laying 4,500 feet of 12 inch main to a remote area of your distribution system. Average flow to this area is expected to be 0.025 MGD. What will be the average detention time (in days) for water in 12 inch main?

Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
= 0.785 x 1 ft x 1 ft x 4,500 ft x 7.48 gal/ft^3 = 26,423.1 gal

$$\text{DT, days} = \frac{26{,}423.1 \text{ gallons}}{25{,}000 \text{ gpd}} = \mathbf{1.06 \text{ days}}$$

25. Find the detention time in hours in a tank that measures 75 ft long by 55 ft wide and 25 ft deep with a flow to the tank of 2,000 gpm.

Vol, gal = L, ft x W, ft x H, ft x 7.48 gal/ft^3
= 75 ft x 55 ft x 25 ft x 7.48 gal/ft^3 = 771,375 gal

$$\text{DT, hr} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{771{,}375 \text{ gal}}{2{,}000 \text{ gpm}} = 385.69 \text{ min} \times \frac{1 \text{ hr}}{60 \text{ min}} \mathbf{= 6.43 \text{ hr}}$$

26. A clearwell is 10 ft deep, 15 ft wide, and 50 feet long. If the flow through the clearwell is 0.50 MGD, what is the detention time in hours?

    Vol, gal = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    = 50 ft x 10 ft x 15 ft x 7.48 gal/ft^3 = 56,100 gal

    $$Q, \text{gpm} = 0.50 \text{ MGD} \times \frac{694.4 \text{ gpm}}{1 \text{ MGD}} = 347.2 \text{ gpm}$$

    $$DT, \text{hours} = \frac{V \text{ (gal)}}{Q \text{ (gpm)}} = \frac{56{,}100 \text{ gal}}{347.2 \text{ gpm}} = 161.6 \text{ min} \times \frac{1 \text{ hr}}{60 \text{ min}} = \mathbf{2.69 \text{ hr}}$$

27. How many hours would it take to use the water in a 175,000 ft. 8 inch pipe with an outflow of 2,500 gpm in an inflow of 500 gpm?

    8 in x (1 ft/12 in) = 0.67 ft

    Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
    = 0.785 x 0.67 ft x 0.67 ft x 175,000 ft x (7.48 gal/ft^3) = 461,273.93 gal

    $$DT,\text{hours} = \frac{\text{Vol, gal}}{\text{flow, gpm}} = \frac{461{,}273.93 \text{ gal}}{(2{,}500 - 500) \text{ gpm}} = \frac{461{,}273.93 \text{ gal}}{2{,}000 \text{ gpm}} = 230.64 \text{ min} \times \frac{1 \text{ hr}}{60 \text{ min}} = \mathbf{3.84 \text{ hr}}$$

28. What amount of 100% chlorine is required to treat 0.25 million gallons of water to provide a 1.4 mg/L dose?

    Feed, lbs = Dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 1.4 mg/L x 0.25 MG x 8.34 lbs/gal = **2.92 lbs**

29. How many pounds of chlorine gas are required to treat 250 gpm of water to provide a 1.6 mg/L residual?

    $$250 \text{ gpm} \times \frac{1 \text{ MGD}}{694.4 \text{ gpm}} = 0.36 \text{ MGD}$$

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 1.6 mg/L x 0.36 MGD x 8.34 lbs/gal= **4.80 lbs**

30. A chlorinator is set to feed 15 pounds of chlorine in 24 hours to a flow of 0.5 MGD. Find the chlorine dose in mg/L.

    Dose, mg/L = Feed (lbs/day) ÷ flow (MGD) ÷ 8.34 lbs/gal
    = 15lbs/day ÷ 0.5 MGD ÷ 8.34 lbs/gal = **3.6 lbs/day**

31. Examination of the raw water shows manganese levels of 0.5 mg/L and total iron levels of 0.3 mg/L. How many pounds of potassium permanganate should be fed to treat 250,000 gallons per day for only iron and manganese?

    Gallons = 250,000 gallons/1MG = 0.25 MG

    Total Permanganate Demand = 1 x (Fe conc, mg/L) + 2 x (Mn conc, mg/L)
    =(1x 0.3 mg/L) + (2 x 0.5 mg/L) = 0.3 mg/L + 1.0 mg/L = 1.3 mg/L

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 1.3 mg/L X 0.25 MG X 8.34 lbs/gal = **2.71 lbs**

32. If chlorine costs $0.51/lb, what is the daily cost to chlorinate 2.5 MGD of water to an initial concentration of 1.4 mg/L?

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 1.4 mg/L x 2.5 MGD x 8.34 lbs/gal = 29.19 lbs/day
    = 29.19 lbs/day x $0.51/lb = **$14.89/day**

33. A rectangular reservoir 100 ft x 50 ft x 25 ft is filled with water. How many pounds of alum must be added in order to produce a dosage of 50 mg/L?

    Vol, gal = L, ft x W, ft x H, ft x 7.48 gal/ft^3

    $$= 100 \text{ ft} \times 50 \text{ ft} \times 25 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 935{,}000 \text{ gal} \times \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} = 0.94 \text{ MG}$$

    Feed, lbs/day = Dose, mg/L x flow, MGD x 8.34 lbs/gal
    = 50 mg/L x 0.94 MG x 8.34 lbs/gal **= 391.98 lbs**

34. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line 4,000 feet long using dosage of 50 mg/L chlorine?

    6 in x 1ft/12 in = 0.5 ft

    Volume = 0.785 x (D, ft)^2 x (L, ft) x 7.48 gal/ft^3

    $$= 0.785 \times 0.5 \text{ ft} \times 0.5 \text{ ft} \times 4{,}000 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 5{,}871.8 \text{ gal} \times \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} = 0.0058 \text{ MG}$$

    $$\text{Feed, lbs/day} = \frac{\text{Dose, mg/L} \times \text{flow, MGD} \times 8.34 \text{ lbs/gal}}{(\%, \text{ as decimal})}$$

    $$= \frac{50 \text{ mg/L} \times 0.0058 \text{ MGD} \times 8.34 \text{ gal/ft}^3}{0.125} = \frac{2.42 \text{ lbs}}{0.125} = 19.36 \text{ lbs} \times \frac{1 \text{ gal}}{8.34 \text{ lbs}} = \mathbf{2.32 \text{ gal}}$$

35. Water from a well is being treated by hypochlorinator. If the hypochlorinator is set at a pumping rate of 16 gpd and uses a 12% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 280 GPM?

$$Q = 280 \text{ gpm} \times \frac{1 \text{ MGD}}{694.4 \text{ gpm}} = 0.40 \text{ MGD}$$

$$\text{Feed, lbs/day} = 16 \text{ gpd} \times \frac{8.34 \text{ lbs}}{1 \text{ gal}} = 133.44 \text{ lbs/day}$$

Dose, mg/L = Feed (lbs/day) ÷ flow (MGD) ÷ 8.34 lbs/gal
= 133.44 lbs/day ÷ 0.40 MGD ÷ 8.34 lbs/gal = 40 mg/L

Dose, mg/L @ 12% solution = 40 mg/L x 0.12 = **4.8 mg/L**

36. A water plant uses 25 gallons of sodium fluoride solution in treating 0.40 MGD of water. Natural fluoride ion is 0.25 mg/L. What is the calculated dosage?

$$\text{Capacity, gpd} = 0.40 \text{ MGD} \times \frac{1{,}000{,}000 \text{ gal}}{1 \text{ MG}} = 400{,}000 \text{ gpd}$$

$$\text{Dose, mg/L} = \frac{\text{Solution Fed,gal} \times 18{,}000 \text{ mg/L}}{\text{Capacity, gdp}}$$

$$= \frac{25 \text{ gal} \times 18{,}000 \text{ mg/L}}{400{,}000 \text{ gpd}} = \frac{450{,}000 \text{ mg/L}}{400{,}000} = \mathbf{1.13 \text{ mg/L}}$$

37. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 275,000 gallons of water. The raw water has a natural fluoride content of 0.2 mg/L and the desired fluoride in the finished water is 1.5 mg/L. How many gallons of feed solution is needed?

$$\text{Fluoride Feed Rate, gpd} = \frac{\text{Dose, mg/L} \times \text{Capacity, gpd}}{18{,}000 \text{ mg/L}}$$

$$= \frac{1.3 \text{ mg/L} \times 275{,}000 \text{ gallons}}{18{,}000 \text{ mg/L}} = \frac{357{,}500 \text{ gal}}{18{,}000} = \mathbf{19.86 \text{ gallons}}$$

38. A diaphragm pump feeds a polyphosphate to the clearwell to treat for iron and manganese. At 100% the pump will put out 250 mL per min. The operator must treat a plant flow of 0.75 MGD with 2.5 mg/L of polyphosphate. The polyphosphate weighs approximately 12 lbs/gallon. What is the pump setting?

    Feed, lbs/day = dose, mg/L x flow, MGD x 8.34 lbs/gal
    2.5 mg/L X 0.75 MGD X 8.34 lbs/gal = 15.64 lbs

    $$\text{Vol, mL/min} = \frac{15.64 \text{ lbs}}{\text{day}} \times \frac{1\text{gal}}{12 \text{ lbs}} \times \frac{3785 \text{ mL}}{1 \text{ gal}} \times \frac{1 \text{ day}}{1440 \text{ min}} = 3.42 \text{ mL}$$

    $$\frac{X\ \%}{3.42 \text{ mL}} = \frac{100\%}{250 \text{ mL}}$$

    $$X = \frac{(100\%)(3.42 \text{ mL})}{250 \text{ mL}} = \frac{342\ \%}{250} = \mathbf{1.37\%}$$

39. The average chlorine residual entering a booster station is 0.2 mg/L. Using a gas chlorine feed system on site, the operator must boost the chlorine to a residual of 2.2 mg/L. The booster pump rated at 0.20 MGD runs 16 hours per day. How many pounds of Cl_2 will be fed per day?

    Volume Treated = 16 hours x 1 day/(24 hours) X 0.20 MGD
    = 0.13 MG

    Dosage Required = 2.2 – 0.2 = 2.0 mg/L

    Feed (lbs/day) = dose (mg/L) x flow (MGD) x 8.34 lbs/gal
    = 2.0 mg/L x 0.20 MGD x 8.34 lbs/gal = **2.17 lbs**

APPENDIX Q - ANSWERS TO: EXERCISES (Alkalinity/Hardness):

1. A 45 mL sample is titrated with 0.01 M H_2SO_4. The endpoint is reached when 13.9 mL of H_2SO_4 have been added. What is the alkalinity concentration?

$$\text{Alkalinity (mg/L as } CaCO_3) = \frac{\text{mL of } H_2SO_4 \text{ X } 1,000}{\text{mL of sample}}$$

$$= (13.9 \text{ mL X } 1000) / (45)$$
$$= \mathbf{308.9 \text{ mg/L as } CaCO_3}$$

2. A 100 mL sample is titrated with 0.02 M H_2SO_4. The endpoint is reached when 21.4 mL of H_2SO_4 have been added. What is the alkalinity concentration?

$$\text{Alkalinity (mg/L as } CaCO_3) = \frac{\text{mL of } H_2SO_4 \text{ X } 1,000}{\text{mL of sample}}$$

$$= (21.4 \text{ mL X } 1000) / (100)$$
$$= \mathbf{214 \text{ mg/L as } CaCO_3}$$

3. A 65 mL sample is titrated with 0.03 M EDTA. The endpoint is reached when 15.3 mL of EDTA have been added. What is the hardness concentration?

______Hardness (mg/L as $CaCO_3$) $= \frac{\text{mL of EDTA X } 1,000}{\text{mL of sample}}$

$$= (15.3 \text{ mL X } 1000) / (65)$$
$$= \mathbf{235.4 \text{ mg/L as } CaCO_3}$$

4. A 115 mL sample is titrated with 0.02 M EDTA. The endpoint is reached when 23.6 mL of EDTA have been added. What is the hardness concentration?

______Hardness (mg/L as $CaCO_3$) $= \frac{\text{mL of EDTA X } 1,000}{\text{mL of sample}}$

$$= (23.6 \text{ mL X } 1000) / (115)$$
$$= \mathbf{205.2 \text{ mg/L as } CaCO_3}$$

APPENDIX R - ANSWERS TO: EXERCISES (Filtration/Backwash):

1. A treatment plant has 4 filters that treat a flow of 1735 gpm. If the filters are 9 feet wide by 16 feet long, what is the loading rate on the filters in gpm/ft^2?

   Filtration Rate (gpm/ft^2) = (flow, gpm) / (Surface Area ft^2)
   = (1735 gpm) / (9 X 16 ft^2)
   = **12.0 gpm/ft^2**

2. A treatment plant has 6 filters that treat a flow of 1.8 MGD. If the filters are 7 feet wide by 15 feet long, what is the loading rate on the filters in gpm/ft^2?

   1.8 MGD / 6 filters = 0.3 MGD

   GPM = 0.3 MGD X (1,000,000 gal / 1440 min)
   GPM = 208.3

   Filtration Rate (gpm/ft^2) = (flow, gpm) / (Surface Area ft^2)
   = (208.3 gpm) / (7 X 15 ft^2)
   = **1.98 gpm/ft^2**

3. A 12-minute back wash at your plant uses 17 gpm. How much backwash water is used?

   Backwash Water, gal = (Backwash Flow, gpm)(Backwash time, min)
   = 17 gpm X 12 min
   = **204 gal**

4. A filter that is 7 feet wide by 12 feet long is backwashed for 3 minutes at a rate of 975 gpm, then for 10 minutes at a rate of 2,020 gpm and then at 975 gpm for another 3 minutes. What are the backwash volume in gal/ ft^2 and the average flow rate in gpm/ft^2?

   Total gallons = (6 min X 975 gpm) + (10 min X 2,020 gpm) = 26,050 gal

   Total gal/ ft^2 = 26050 gal / (7 ft X 12 ft) = **310 gal/ft^2**

   Gal/min/ft^2 = (310 gal/ft^2) / 16 min = **19.4 gpm/ft^2**

5. Your backwash ratio is 34 gpm for 14 minutes each day. What percentage of your total daily production of 635,000 gallons is used for backwash?

   Backwash Water, gal = (Backwash Flow, gpm)(Backwash time, min)
   = (34 gpm) (14 min)
   = 476 gal

   Backwash % = (Backwash Water, gal X 100%) / Water Filtered, gal
   = (476 gal X 100%) / 635,000 gal
   = **7.5%**

APPENDIX R - ANSWERS TO: EXERCISES (Filtration/Backwash) CONTINUED:

6. The backwash ratio is 22 gpm per ft^2 for 12 minutes each day. The filter is 21 feet by 14 feet. What percentage of your total daily production of 775,000 gallons is used for backwash?

   A, ft^2 = 21 ft X 14 ft = 294 ft^2

   Backwash Water, gal = (Backwash Flow, gpm)(Backwash time, min)
   = (22 gpm/ ft^2) X (12 min) X (294 ft^2)
   = 77,616 gal

   Backwash % = (Backwash Water, gal X 100%) / Water Filtered, gal
   = (77,616 gal X 100%) / 775,000 gal
   = **10%**

APPENDIX S - ANSWERS TO: CLASS II MATH EXAM PREP – IN CLASS:

Regulations

1. Calculate the 90th percentile for lead using the following data: 0.007 mg/L, 0.016 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L.

   90th Percentile = 5 x 0.9 = 4.5

   $$= \frac{(\#5+\#4)}{2} = \frac{(0.018 + 0.016)\ \text{mg/L}}{2} = \frac{0.034\ \text{mg/L}}{2} = \mathbf{0.017\ mg/L}$$

2. A water sample has the following results:

   Bromodichloromethane 0.018 mg/L
   Chloroform 0.038 mg/L
   Bromoform 0.002 mg/L
   Dibromochloromethane 0.006mg/L

   (0.018 + 0.038 + 0.002 + 0.006) mg/L = **0.064 mg/L**

3. The average working pressure on a water main that has just been laid will be 85 psi. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

   85 psi x 1.5 = 127.5 psi < 150 psi
   Test pipe at **150 psi**

4. Bed Rock PSD is installing a 5,000 feet of 6-inch main. How many bacteriological samples must be collected before placing the main into service?

   Samples every 1,200 ft plus the end = 5,000/1,200 = 4.16
   = 4 + 1 (end) = 5 x 2 (2 sets) = **10 total**

5. During a water meter test for accuracy, 200 gallons were allowed to flow through a meter. The meter registered that 192.3 gallons flowed through the meter during the test. What is the accuracy of the meter in percent?

   $$\text{Meter Accuracy} = \frac{\text{Volume of water registered, gal}}{\text{Actual volume, gal}} \times 100\%$$

   $$= \frac{192.3\ \text{gal}}{200\ \text{gal}} \times 100\% = \mathbf{96.15\%}$$

Conversions

6. Convert 25° Celsius to Fahrenheit

   F = (1.8 x C°) + 32 = (1.8 x 25°) + 32 = 45° + 32 = **77°**

7. A 3.25% chlorine solution is what concentration in mg/L?

   3.25 % x (10,000 mg/L / 1 %) = **32,500 mg/L**

8. Convert 200 mg/L to grains per gallons.

   200 mg/L x (1 gpg/17.12 mg/L) = **11.68 gpg**

9. Convert 10.8 grains per gallons to mg/L of hardness.

   10.8 gpg x (17.12 mg/L/1 gpg) = **184.9 mg/L**

10. The overflow of a water tank is located 900 feet above a neighborhood fire hydrant. Not accounting for c-factor of the pipe, what is the water pressure at the hydrant when the tank is full?

    900 ft x (1 psi/2.31 ft) = **389.61 psi**

11. The bottom of a standpipe tank is 1,250 above sea level. The tank has a 30 feet diameter and stands 50 feet tall and is 75% full. What is the pressure in pounds per square inch of standing water in the fire hydrant in a valley that has an elevation of 650 feet above sea level?

    h (tank) = 50 ft x 0.75 = 37.5 ft

    Elevation (water level) = Tank Height + Elevation at bottom of tank
    Elevation (water level) = 37.5 ft + 1,250 ft = 1,287.5 ft

    Head (ft) = Elevation (water level) - Elevation (fire hydrant)
    Head (ft) = 1,287.5 ft - 650 ft = 637.5 ft

    Pressure (psi) = 637.5 ft x (1 psi/2.31 ft) = **275.97 psi**

12. What is the smallest size pump (in gpm) that is needed to produce twice the daily average of 250,000 gpd?

    2Q = 2 (250,000 gpd) = 500,000 gpd x (1 day/1440 min) = **347.22 gpm**

    Therefore, of the pumps listed, you would need the 400 gal/min pump.

13. A ferric chloride pump is calibrated by timing to deliver 420 milliliter in 15 seconds. How much coagulant is being added in gallons per minute?

    420 mL x (1 L/1,000 mL) = 0.42 L x (1 gal/3.785L) = 0.11 gal

    15 sec x (1 min/60 sec) = 0.25 min

    $$\text{Pump rate} = \frac{\text{Volume, gal}}{\text{time, min}} = \frac{0.11 \text{ gal}}{0.25 \text{ min}} = \mathbf{0.44\ gpm}$$

14. A filter that had been in service for 3 days, filtered 3.4 MG. If the filter is 12 feet wide by 18 feet in length, what was the average flow rate through the filter in gpm?

    3.4 MG x (1,000,000 gal/1 MG) = 3,400,000 gal

    3 day x (1,440 min/1 day) = 4,320 min

    $$\text{Filtration rate} = \frac{\text{Volume, gal}}{\text{Time, min}} = \frac{3{,}400{,}000 \text{ gal}}{4{,}320 \text{ min}} = \mathbf{787.04\ gpm}$$

Miscellaneous

15. A water system analytical results indicates an iron level of 1.3 mg/L and a manganese level of 0.5 mg/L. Determine the estimated demand of potassium permanganate.

    $KMnO_4$ dosage, mg/L = 1(Fe concentration) + 2(Mn Concentration)
    = 1(1.3 mg/L) + 2(0.5 mg/L) = 1.3 mg/L + 1.0 mg/L = **2.3 mg/L**

16. A 50 milliliter sample is titrated with 0.01 M EDTA. The endpoint is reached when 14.2 milliliters of EDTA have been added. The hardness concentration is:

    $$\text{Hardness} = \frac{\text{mL of EDTA} \times 1{,}000}{50 \text{ mL}} = \frac{14.2 \text{ mL} \times 1{,}000}{50 \text{ mL}} = \frac{14{,}200}{50} = \mathbf{284\ mg/L}$$

Volume

17. What is the minimum amount of water that will be used to disinfect a 10 inch main that is 20,000 feet long to 50 ppm and flush the main?

    10 in x (1 ft/12 in) = 0.83 ft

    Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
    = 0.785 x 0.83 ft x 0.83ft x 20,000 ft x 7.48 gal/ft^3 = 80,901.66 gal
    = 80,901.66 gal x 2 = **161,803.32 gal**

18. What is the minimum amount of water that will be needed to flush an 8 inch main that is 22,000 feet long for 15 minutes prior to disinfection and for 30 minutes after the water in line has been left standing for 6 hours? The water will pump at 400 gpm.

    2V, gal = Q, gpm x t, min
    = 2 x {400 gpm x (15 min + 30 min)} =
    = 2 x (400 gpm x 45 min) = 2 x 18,000 gal = **36,000 gal**

19. A water system with 17,005 feet of 14 inch mains, 8,523 feet of 8 inch mains, 12,000 feet of 6 inch distribution line, 2 storage tanks 35 feet in diameter and 28 feet high to the overflow. The clear well at the plant is 55 feet x 35 feet x 20 feet. How many gallons of water does it take to fill the system to capacity?

    14 inch x 1 ft/12 inch = 1.17 ft
    8 inch x 1 ft/12 inch = 0.67 ft
    6 inch x 1 ft/12 inch = 0.50 ft

    V_1 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_1 = 0.785 x 1.17 ft x 1.17 ft x 17,005 ft x 7.48 gal/ft^3 = 136,684.6 gal

    V_2 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_2 = 0.785 x 0.67 ft x 0.67 ft x 8,523 ft x 7.48 gal/ft^3 = 22,465.36 gal

    V_3 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_3 = 0.785 x 0.50 ft x 0.50 ft x 12,000 ft x 7.48 gal/ft^3 = 17,615.4 gal

    V_4 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_4 = 0.785 x 35 ft x 35 ft x 28 ft x 7.48 gal/ft^3 = 201,402.74 gal
    V_4 = 2 x (201,402.74 gal)
    V_4 = 402,805.48 gal

    V_4 = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    V_4= 55 ft x 35 ft x 20 ft x 7.48 gal/ft^3 = 287,980 gal

    $V = V_1 + V_1 + V_3 + V_4 + V_5$
    V = 136,684.6 gal + 22,465.36 gal + 17,615.4 gal + 402,805.48 gal + 287,980 gal
    = **867,550.84 gal**

<u>Detention Time</u>

20. During a 30 minute pumping test, 2,785 gallons are pumped into a tank with a diameter of 10 feet. The water level before the pumping test was 3 feet. What is the gpm rate?

    $$\text{Q, gpm} = \frac{\text{volume, gal}}{\text{time, min}} = \frac{2{,}785 \text{ gal}}{30 \text{ min}} = \mathbf{92.8\ gpm}$$

21. What is the theoretical detention time (in hours) for sedimentation basin of a 5 MGD plant with the dimensions of 50 feet by 140 feet by 10 feet?

    5 MGD x (694.4 gpm/1 MGD) = 3,472 gpm

    V = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    = 50 ft x 140 ft x 10 ft x 7.48 gal/ft^3 = 523,600 gal
    = 523,600 gal

    $$\text{D.T., min} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{523{,}600 \text{ gal}}{3{,}472 \text{ gpm}} = 150.81 \text{ min} \times (1 \text{ hr}/60 \text{ min}) = \mathbf{2.51 \text{ hours}}$$

22. An empty storage tank is 12 feet in diameter and 52 feet high. How long (in hours) will it take to fill 80% of the tank volume if a pump is discharging a constant 35 gallons per minute into the tank?

    Height = 52 ft x 0.8 = 41.6 ft

    Volume = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 12 ft x 12 ft x 41.6 ft x 7.48 gal/ft^3 = 35,174.43 gal

    $$\text{D.T., min} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{35{,}174.43 \text{ gal}}{35 \text{ gpm}} = 1{,}004.98 \text{ min} \times (1 \text{ hr}/60 \text{ min}) = \mathbf{16.75 \text{ hours}}$$

23. Calculate the detention time long (in hours) for a sedimentation tank that is 50 feet wide, 140 feet long, and 10 feet deep with a flow of 5.3 MGD.

    5.3 MGD x (694.4 gpm/1 MGD) = 3680.32 gpm

    V = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    = 50 ft x 140 ft x 10 ft x 7.48 gal/ft^3 = 523,600 gal
    = 523,600 gal

    $$\text{D.T., min} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{523{,}600 \text{ gal}}{3{,}680.32\text{gpm}} = 142.27 \text{ min} \times (1 \text{ hr}/60 \text{ min}) = \mathbf{2.37 \text{ hours}}$$

<u>Fluoridation</u>

24. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 200,000 gallons of water. The raw water has a natural fluoride content of 0.2 mg/L and the desired fluoride in the finished water is 1.1 mg/L. How many gallons of feed solution is needed?

    Dose (mg/L) = 1.1 mg/L - 0.2 mg/L = 0.9 mg/L

    $$\text{Feed Rate (gpd)} = \frac{\text{Dose (mg/L) X Capacity (gpd)}}{18{,}000 \text{ mg/L}}$$

    $$\text{Feed Rate (gpd)} = \frac{0.9 \text{ mg/L X } 200{,}000 \text{ gpd}}{18{,}000 \text{ mg/L}} = \frac{180{,}000}{18{,}000} = \mathbf{10 \text{ gpd}}$$

25. The natural fluoride level in the 956,000 gallons of water produced is 0.12 mg/L. The 55 gallon HFS day tank has a tare weight of 5 lbs. Eight gallons at 9.2 lbs. per gallon of the 28% HFS is being pumped daily into the clearwell. Calculate the fluoride dosage for your system.

    956,000 gal x (1 MG/1,000,000 gal) = 0.96 MGD

    8 gallons x 9.2 lbs/gal. = 73.6 lbs

    $$\text{Dose (mg/L)} = \frac{\text{Feed rate (lbs/day) x AFI x chemical purity (decimal)}}{\text{Capacity (MGD) x (8.34 lbs/gal)}}$$

    $$\text{Dose (mg/L)} = \frac{\text{73.6 lbs x 0.28 purity x 0.792 AFI}}{\text{0.96 MGD x 8.34 lbs/gal}} = \frac{\text{16.32 mg/L}}{8.01} = \textbf{2.04 mg/L}$$

26. Your EW-80 indicates an average of 5.3 pounds per day of granular sodium fluoride has been added to the average of 155,000 gallons of finished water for the last 30 days. What is the dose of fluoride in the water supply.

    155,000 gal x (1 MG/1,000,000 gal) = 0.16 MGD

    $$\text{Dose (mg/L)} = \frac{\text{Feed rate (lbs/day) x AFI x chemical purity (decimal)}}{\text{Capacity (MGD) x (8.34 lbs/gal)}}$$

    $$\text{Dose (mg/L)} = \frac{\text{5.3 lbs x 0.453 AFI x 0.98 purity}}{\text{0.16 MGD x 8.34 lbs/gal}} = \frac{\text{2.35 mg/L}}{1.33} = \textbf{1.77 mg/L}$$

<u>Pounds/Dosage</u>

27. 0.1116 lb/min of soda ash is fed into 1,525,000 gal/day of treated water. What is the soda ash dosage?

    1,525,000 gal/day x (1 MG/1,000,000 gal) = 1.53 MGD

    0.1116 lb/min x (1,440 min/1 day) = 160.7 lb/day

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 lb/gal
    = 160.7 lbs/day ÷ 1.53 MGD ÷ 8.34 lb/gal = **12.59 mg/L**

28. What is the dosage (of/where) 12 lbs of chlorine gas is added to 450,000 gallons of finished water?

    Q (MGD) = 450,000 gal/day x (1 MG/1,000,000 gal) = 0.45 MGD

    Dose (mg/L) = Feed (lb/day) ÷ Q (MGD) ÷ (8.34 lb/gal)
    = 12 lb/day ÷ 0.45 MGD ÷ 8.34 lb/gal = **3.20 mg/L**

29. The operator feeds 25% (W/W) liquid caustic soda to adjust the pH of the filtered water. The plant pumps 1.5 MGD and feeds the liquid at a constant rate of 37 ppm. The 25% caustic soda weighs 12 lbs per gallon. How much caustic soda by dry weight is fed in a day?

    Feed (lbs/day) = dose (mg/L) x flow (MGD) x 8.34 lbs/gal
    = 37 mg/L x 1.5 MGD x 8.34 lbs/gal = 462.87 lbs/day
    = 462.87 lbs/day x 0.25 = **115.72 lbs/day**

30. Determine the setting on a potassium permanganate chemical feed pump in pounds per day if the demand is determined to be 2.2 ppm, the desired permanganate residual is 0.2 ppm and the flow is 0.45 MGD.

    Dose (mg/L) = Demand (mg/L) + Residual (mg/L)
    Dose (mg/L) = 2.2 mg/L + 0.2 mg/L
    Dose (mg/L) = 2.4 mg/L

    Feed (lb/day) = Dose (mg/L) X Q (MGD) X (8.34 lb/gal)
    Feed (lb/day) = (2.4 mg/L) (0.45 MGD) (8.34 lb/gal) = **9.01 lb/day**

31. A system has a well that produces 200 gpm and a 1,500 gallon storage tank. There are 105 homes on the systems and the average daily consumption is 300 gallons/home. A chlorine dosage of 1.3 ppm is maintained using 65% HTH. How many pounds of HTH must be purchased each year?

    105 homes x 300 gallons/day/home = 31,500 gpd = 0.032 MGD

    $$\text{lbs/day} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{1.3 mg/L x 0.032 MGD x 8.34 lb/gal}}{0.65} = \frac{\text{0.35 lb/day}}{0.65} = \text{0.53 lb/day}$$

    0.53 lbs/day x 365 days/year = **194.82 lbs/year**

32. How many pounds of HTH (65%) are needed to disinfect at 50 ppm a 10-inch diameter line that is 20,000 feet long?

    10 inch x (1 ft/12) inch = 0.83 ft

    Volume = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 0.83 ft x 0.83 ft x 20,000 ft x 7.48 gal/ft^3 = 80,901.66 gal

    80,901.66 gal/day x (1 MG/1,000,000 gal) = 0.081 MGD

    $$\text{Feed (lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{50 mg/L x 0.081 MGD x 8.34 lb/gal}}{0.65} = \frac{\text{33.78 lb/day}}{0.65} = \textbf{51.97 lb/day}$$

33. How many pounds of 65% HTH are needed to shock a 10 inch diameter pipe that is 2,100 feet long to 50 ppm of chlorine residual?

    10 inch x (1 ft/12 inch) = 0.83 ft

    Volume, gal = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 0.83 ft x 0.83 ft x 2,100 ft x 7.48 gal/ft^3 = 8,494.67 gal

    8,494.67 gal/day x (1 MG/1,000,000 gal) = 0.0085 MGD

    $$\text{Feed (lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{50 mg/L x 0.0085 MGD x 8.34 lb/gal}}{0.65} = \frac{\text{3.54 lb/day}}{0.65} = \textbf{5.45 lb/day}$$

34. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 1 to disinfect the tank. This method requires that the tank be filled to the overflow with enough chlorine added to the water to have a 10 mg/L residual in the tank after a 24 hour retention time. The tank holds 2,500,000 gallons filled to the overflow. It has been determined that the initial chlorine dose needs to be 25 mg/L. How many pounds of HTH 65% available chlorine will it take to get the required dose?

    $$\text{(lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{25 mg/L x 2.50 MGD x 8.34 lb/gal}}{0.65} = \frac{\text{521.25 lb/day}}{0.65} = 8\textbf{01.92 lb/day}$$

35. A treatment plant disinfects a flow of 0.75 MGD with 8.25% sodium hypochlorite to a dose of 2.0 mg/L. The sodium hypochlorite solution has a specific gravity of 1.8. How many gallons of sodium hypochlorite will the plant use per day?

    Weight of substance (lb/gal) = Sp. Gr. x weight of water (lb/gal)
    = 1.8 x 8.34 lb/gal = 15.01 lb/gal

    $$\text{(lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{2.0 mg/L x 0.75 MGD x 8.34 lb/gal}}{0.0825} = \frac{\text{12.51 lb/day}}{0.0825} = \text{151.64 lb/day}$$

    gpd = 151.64 lb/gal x (1 gal/15.01 lb/gal) = **10.10 gpd**

36. A chlorine pump is feeding 12% bleach (1 gallon = 9.48 pounds) at a dosage of 2.0 mg/L. If 525,000 gallons are treated in 16 hours, how many gallons per hour is the pump feeding?

    525,000 gal/day x (1 MG/1,000,000 gal) = 0.53 MGD

    $$(\text{lb/day}) = \frac{\text{dose, mg/L} \times \text{flow, MGD} \times 8.34 \text{ lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{2.0 \text{ mg/L} \times 0.53 \text{ MGD} \times 8.34 \text{ lb/gal}}{0.12} = \frac{8.84 \text{ lb/day}}{0.12} = 74.67 \text{ lb/day}$$

    g/hr = 74.67 lb/gal x (1 gal/9.48 lb/gal) = 7.88 gpd x (1day/16 hr) = **0.49 gal/hr**

Filtration/Backwash

37. A treatment plant with dual filters processes a flow of 0.75 MGD. If the filters are 10 feet wide by 10 feet in length, what is the filtration rate?

    0.75 MGD x (694.4 gpm/1 MGD) = 520.8 gpm

    Area, ft^2 = length, feet x width, feet = 10 ft x 10 ft = 100 ft^2

    $$\text{Flow, gpm} = \frac{\text{flow, gpm}}{\text{\# of filters}} = \frac{520.8 \text{ gpm}}{2} = 260.4 \text{ gpm}$$

    $$\text{Filtration Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{260.4 \text{ gpm}}{100 \text{ ft}^2} = \mathbf{2.60 \text{ gpm/ft}^2}$$

38. A treatment plant with 4 sand filters treats a flow of 2.4 MG in 24 hours with two backwashes at the end of the run. If the filters are 10 feet wide by 20 feet in length, what is the loading rate on the filters in gpm/ft^2?

    2.4 MGD x (694.4 gpm/1 MGD) = 1,666.56 gpm

    Area, ft^2 = length, feet x width, feet = 10 ft x 20 ft = 200 ft^2

    $$\text{Flow, gpm} = \frac{\text{flow, gpm}}{\text{\# of filters}} = \frac{1{,}666.56 \text{ gpm}}{4} = 416.64 \text{ gpm}$$

    $$\text{Filtration Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{416.4 \text{ gpm}}{200 \text{ ft}^2} = \mathbf{2.08 \text{ gpm/ft}^2}$$

39. A filter that is 10 feet wide by 15 feet in length is backwashed for 3 minutes at a low rate of 1,100 gpm, then for 9 minutes at a high rate of 2,200 gpm and then at a low rate of 1,100 gpm for 3 minutes. What was the backwash run volume in gallons per square feet and the average flow rate in gpm/ft^2 ?

    Area, ft^2 = length, feet x width, feet = 10 ft x 15 ft = 150 ft^2

    Flow, gal = (6 min. x 1,100 gpm) + (9 min. x 2,200 gpm)
    = 6,600 gal + 19,800 gal = 26,400 gal

    $$\text{Backwash Vol, g/sq ft} = \frac{\text{Flow, gal}}{\text{Surface area, sq ft}} = \frac{26{,}400\ \text{gal}}{150\ ft^2} = 176\ gal/ft^2$$

    $$\text{Average flow rate, } gpm/ft^2 = \frac{176\ gal/ft^2}{15\ \text{min}} = \mathbf{11.73\ gpm/ft^2}$$

40. Determine the backwash pumping rate in gpm for a filter 10 feet long by 15 feet wide if the backwash is 20 gpm per square foot?

    Area, ft^2 = length, feet x width, feet = 10 ft x 15 ft = 150 ft^2

    Backwash rate, gpm = Backwash rate, gpm/ft^2 x Area, ft^2
    = 20 gpm/ft^2 x 150 ft^2 = **3,000 gpm**

41. What percent of your total daily production of 500,000 gallons is used for backwash? The backwash ratio is 22.5 gpm per sq ft for 15 minutes each day through a filter that is 10 feet by 10 feet.

    Area, ft^2 = length, feet x width, feet = 10 ft x 10 ft = 100 ft^2

    Backwash Water, gal = Backwash Flow, gpm/ft^2 x Backwash Time, min x Area, ft^2
    = 22.5 gpm/ft^2 x 15 min x 100 ft^2 = 33,750 gal

    $$\text{Backwash \%} = \frac{\text{Volume, gal of Backwash}}{\text{Volume, gal total daily production}} \times 100\%$$

    $$\text{Backwash \%} = \frac{33{,}750\ \text{gal}}{500{,}000\ \text{gal}} \times 100\% = \mathbf{6.75\%}$$

Combination

42. You receive a bulk truckload of NaOCl and the receiving slip states the net weight is 52,360 lbs. The certificate of analysis indicates the specific gravity is 1.22 and the trade % is 16. How many gallons of NaOCl should you receive? If the quoted cost was $0.75/gal., delivered, how much will you pay for the load? If you have two empty 2,100 gallon bulk tanks and a 300 gallon day tank with 120 gallons in it, will you be able to take the entire shipment?

    Weight of substance (lb/gal) = Sp. Gr. x weight of water (lb/gal)
    = 1.22 x 8.34 lb/gal = 10.18 lb/gal

    52,360 lbs x (1 gal/10.18 lbs)= **5,143.42 gal**

    5,143.42 gal x $0.75 = **$3,857.57**

    5,143.42 gal – {(2 x 2,100 gal) + (300 gal – 120 gal)}
    = 5,143.42 gal - (4,200 gal +180 gal) = 5,143.42 gal – 4,380 gal = **763.42, No**

43. The liquid alum feed pump is set at 100% stroke and at 100% speed the pump will feed 67 gpd of solution. What speed should the pump setting be if the plant produces 3.2 MGD? The liquid alum is being dosed from the jar tests results at 10 mg/L. The liquid alum delivered to the plant contains 5.36 pound of alum per gallon of liquid solution.

    Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal)
    = 10 mg/L x 3.2 MGD x 8.34 lbs/gal = 266.88 lbs/day

    266.88 lbs/day x (1 gal/5.36 lbs) = 49.79 gpd

    $\frac{A1}{A2} = \frac{B1}{B2}$ $\frac{A1}{49.79 \text{ gpd}} = \frac{100\%}{67 \text{ gpd}}$. $A1 = \frac{100\% \times 49.79 \text{ gpd}}{67 \text{ gpd}} = \frac{4{,}979\%}{67} =$ **74.31%**

44. Due to flooding in the area, the City of Bedrock is in short supply of their 5.75% hypochlorite solution. They have contacted Flintstone PSD and asked to borrow enough 15.3% hypochlorite solution to produce 750 gallons of a 5.75% solution. Determine how many gallons of water and 15.3% hypochlorite are required to produce the desired percentage. The 750 gallon day tank has a diameter of 5 feet and is 25 feet tall. The 15.3% hypochlorite solution has a specific gravity of 1.28.

    $\frac{A1}{A2} = \frac{B1}{B2}$ $\frac{A1}{5.75\%} = \frac{750 \text{ gal}}{15.3\%}$. $A1 = \frac{750 \text{ gal} \times 5.75\%}{15.3\%} = \frac{4{,}312.5 \text{ gal}}{15.3} =$ **281.86 gal**

    282 gallons of 15.3% and 468 gallons of water

45. What is the dosage in mg/L, when 6 gph of a 5.25% hypochlorite solution is fed into a flow of 450 gpm? One gallon of hypochlorite weighs 9.02 pounds.

    lb/day = 6 gph x (24 hr/1 day) x (9.02lb/1 gal) = 1,298.88 gpd
    = 1,298.88 gpd x 0.0525 = 68.19 lb/day

    flow = 450 gpm x (1 MGD/694.4 gpm) = 0.65 MGD

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 #/gal
    = 68.19 lbs/day ÷ 0.65 MGD ÷ 8.34 #/gal = **12.59 mg/L**

46. During a one-week time period, the water meter indicated that 2,250,000 gallons of water were pumped. A three percent sodium hypochlorite solution is stored in a three-foot diameter plastic tank and stored in a nearby room is a partially filled one-hundred pound chlorine cylinder. During this one-week period, the level of hypochlorite in the tank dropped 2 feet 10 inches. Calculate the chlorine dose assuming the one-hundred pound cylinder has sixty pounds remaining in the cylinder?

    2 ft 10 inch = {(2 ft x (12 in/1ft) + 10 in} = (24 in + 10 in) = 34 in
    34 in x (1 ft/12 in) = 2.83 ft

    Hypochlorite, gal = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 3 ft x 3 ft x 2.83 ft x 7.48 gal/ft^3 = 149.55 gal

    Hypochlorite, lbs/day = 149.55 gal x (8.34 lb/1 gal) = 1,247.25 lb
    = 1,247.25 lb x 0.03 = 37.42 lb

    Flow, MGD = 2,250,000 gal x (1 MGD/1,000,000 gal) = 2.25 MGD

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 lb/gal
    = 37.42 lbs/day ÷ 2.25 MGD ÷ 8.34 lb/gal = **1.99 mg/L**

APPENDIX T - ANSWERS TO: CLASS II EXAM MATH PREP – HOMEWORK

Regulations

1. Calculate the 90th percentile for lead using the following data: 0.007 mg/L, 0.026 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L.

   90th Percentile = 5 x 0.9 = 4.5

   $$= \frac{(\#5+\#4)}{2} = \frac{(0.026 + 0.018)\ \text{mg/L}}{2} = \frac{0.044\ \text{mg/L}}{2} = \mathbf{0.022\ mg/L}$$

2. A water sample has the following results:
   - Bromodichloromethane 0.028 mg/L
   - Chloroform 0.038 mg/L
   - Bromoform 0.002 mg/L
   - Dibromochloromethane 0.006mg/L

   (0.028 + 0.038 + 0.002 + 0.006) mg/L = **0.074 mg/L**

3. The average working pressure on a water main that has just been laid will be 105 psi. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

   105 psi x 1.5 = 157.5 psi > 150 psi
   Test pipe at **157.5 psi**

4. Bed Rock PSD is installing a 3,500 feet of 6-inch main. How many bacteriological samples must be collected before placing the main into service?

   Samples every 1,200 ft plus the end = 3500/1200 = 2.91
   = 2 + 1 (end) = 3 x 2 (2 sets) = **6 total**

5. During a water meter test for accuracy, 125 gallons were allowed to flow through a meter. The meter registered that 122.3 gallons flowed through the meter during the test. What is the accuracy of the meter in percent?

   $$\text{Meter Accuracy} = \frac{\text{Volume of water registered, gal}}{\text{Actual volume, gal}} \times 100\%$$

   $$= \frac{122.3\ \text{gal}}{125\ \text{gal}} \times 100\% = \mathbf{97.84\%}$$

Conversions

6. Convert 21° Celsius to Fahrenheit

   F = (1.8 x C°) + 32 = (1.8 x 21°) + 32 = 37.8° + 32 = **69.8**°

7. A 7.25% chlorine solution is what concentration in mg/L?

   7.25 % x (10,000 mg/L / 1 %) = **72,500 mg/L**

8. Convert 222 mg/L to grains per gallons.

   222 mg/L x (1 gpg/17.12 mg/L) = **12.97 gpg**

9. Convert 12.4 grains per gallons to mg/L of hardness.

   12.4 gpg x (17.12 mg/L/1 gpg) = **212.29 mg/L**

10. The overflow of a water tank is located 120 feet above a neighborhood fire hydrant. Not accounting for c-factor of the pipe, what is the water pressure at the hydrant when the tank is full?

    120 ft x (1 psi/2.31 ft) = **51.95 psi**

11. The bottom of a standpipe tank is 1,000 above sea level. The tank has a 30 feet diameter and stands 70 feet tall and is 75% full. What is the pressure in pounds per square inch of standing water in the fire hydrant in a valley that has an elevation of 650 feet above sea level?

    h (tank) = 70 ft x 0.75 = 52.5 ft

    Elevation (water level) = Tank Height + Elevation at bottom of tank
    Elevation (water level) = 52.5 ft + 1,000 ft = 1,052.5 ft

    Head (ft) = Elevation (water level) - Elevation (fire hydrant)
    Head (ft) = 1,052.5 ft - 650 ft = 402.5 ft

    Pressure (psi) = 402.5 ft x (1 psi/2.31 ft) = **174.24 psi**

12. What is the smallest size pump (in gpm) that is needed to produce twice the daily average of 170,000 gpd?

    2Q = 2 (170,000 gpd) = 340,000 gpd x (1/day/1,440 min) = **236.11 gpm**

    Therefore, of the pumps listed, you would need the 240 gal/min pump.

13. A ferric chloride pump is calibrated by timing to deliver 520 milliliter in 15 seconds. How much coagulant is being added in gallons per minute?

    520 mL x (1 L/1,000 mL) = 0.52 L x (1 gal/3.785L) = 0.14 gal

    15 sec x (1 min/60 sec) = 0.25 min

    Pump rate = 0.14 gal/0.25 min = **0.55 gpm**

14. A filter that had been in service for 3 days, filtered 2.4 MG. If the filter is 12 feet wide by 18 feet in length, what was the average flow rate through the filter in gpm?

    2.4 MG x (1,000,000 gal/1 MG) = 2,400,000 gal

    3 day x (1,440 min/1 day) = 4,320 min

    2,400,000 gal/4,320 min = **555.56 gpm**

Miscellaneous

15. A water system analytical results indicates an iron level of 1.8 mg/L and a manganese level of 0.55 mg/L. Determine the estimated demand of potassium permanganate.

    $KMnO_4$ dosage, mg/L = 1(Fe concentration) + 2(Mn Concentration)
    = 1(1.8 mg/L) + 2(0.55 mg/L) = 1.8 mg/L + 1.1 mg/L = **2.9 mg/L**

16. A 50 milliliter sample is titrated with 0.01 M EDTA. The endpoint is reached when 18.2 milliliters of EDTA have been added. The hardness concentration is:

    $$\text{Hardness} = \frac{\text{mL of EDTA} \times 1{,}000}{50 \text{ mL}} = \frac{18.2 \text{ mL} \times 1{,}000}{50 \text{ mL}} = \frac{18{,}200}{50} = \mathbf{364\ mg/L}$$

Volume

17. What is the minimum amount of water that will be used to disinfect a 10 inch main that is 18,000 feet long to 50 ppm and flush the main?

    10 in x (1 ft/12 in) = 0.83 ft

    Vol, gal = 0.785 x D, ft x D, ft x L, ft x 7.48 gal/ft^3
    = 0.785 x 0.83 ft x 0.83ft x 18,000 ft x 7.48 gal/ft^3 = 72,811.49 gal
    = 72,811.49 gal x 2 = **145,622.99 gal**

18. What is the minimum amount of water that will be needed to flush an 8 inch main that is 22,000 feet long for 15 minutes prior to disinfection and for 30 minutes after the water in line has been left standing for 6 hours? The water will pump at 450 gpm.

    2V, gal = Q, gpm x t, min
    = 2 x {450 gpm x (15 min + 30 min)} =
    = 2 x (450 gpm x 45 min) = 2 x 20,250 gal = **40,500 gal**

19. A water system with 7,000 feet of 14 inch mains, 8,000 feet of 8 inch mains, 12,000 feet of 6 inch distribution line, 2 storage tanks 35 feet in diameter and 28 feet high to the overflow. The clear well at the plant is 55 feet x 35 feet x 20 feet. How many gallons of water does it take to fill the system to capacity?

    14 inch x (1 ft/12 inch) = 1.17 ft
    8 inch x (1 ft/12 inch) = 0.67 ft
    6 inch x (1 ft/12 inch) = 0.50 ft

    V_1 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_1 = 0.785 x 1.17 ft x 1.17 ft x 7,000 ft x 7.48 gal/ft^3 = 56,265.35 gal

    V_2 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_2 = 0.785 x 0.67 ft x 0.67 ft x 8,000 ft x 7.48 gal/ft^3 = 21,086.81 gal

    V_3 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_3 = 0.785 x 0.50 ft x 0.50 ft x 12,000 ft x 7.48 gal/ft^3 = 17,615.4 gal

    V_4 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_4 = 0.785 x 35 ft x 35 ft x 28 ft x 7.48 gal/ft^3 = 201,402.74 gal
    V_4 = 2 x (201,402.74 gal)
    V_4 = 402,805.48 gal

    V_4 = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    V_4= 55 ft x 35 ft x 20 ft x 7.48 gal/ft^3 = 287,980 gal

    $V = V_1 + V_1 + V_3 + V_4 + V_5$
    V = 56,265.35 gal + 21,086.81 gal + 17,615.4 gal + 402,805.48 gal + 287,980 gal
    = **785,753.04 gal**

<u>Detention Time</u>

20. During a 30 minute pumping test, 3,750 gallons are pumped into a tank with a diameter of 10 feet. The water level before the pumping test was 3 feet. What is the gpm rate?

    $$\text{Q, gpm} = \frac{\text{volume, gal}}{\text{time, min}} = \frac{3{,}750\text{ gal}}{30\text{ min}} = \mathbf{125\ gpm}$$

21. What is the theoretical detention time (in hours) for sedimentation basin of a 4.75 MGD plant with the dimensions of 150 feet by 40 feet by 10 feet?

    4.75 MGD x (694.4 gpm/1 MGD) = 3,298.4 gpm

    V = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    = 150 ft x 40 ft x 10 ft x 7.48 gal/ft^3 = 448,800 gal
    = 523,600 gal

    $$\text{D.T., min} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{448{,}800\text{ gal}}{3{,}298.4\text{ gpm}} = 136.07\text{ min x (1 hr/60 min)} = \mathbf{2.27\ hours}$$

22. An empty storage tank is 15 feet in diameter and 30 feet high. How long (in hours) will it take to fill 75% of the tank volume if a pump is discharging a constant 30 gallons per minute into the tank?

    Height = 30 ft x 0.75 = 22.5 ft

    Volume = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 15 ft x 15 ft x 22.5 ft x 7.48 gal/ft^3 = 29,725.99 gal

    $$\text{D.T., min} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{29{,}725.99\ \text{gal}}{30\ \text{gpm}} = 990.87\ \text{min} \times (1\ \text{hr}/60\ \text{min}) = \mathbf{16.51\ hours}$$

23. Calculate the detention time long (in hours) for a sedimentation tank that is 150 feet wide, 40 feet long, and 10 feet deep with a flow of 4.6 MGD.

    4.6 MGD x (694.4 gpm/1 MGD) = 3194.24

    V = L, ft x W, ft x H, ft x 7.48 gal/ft^3 = 150 ft x 40 ft x 10 ft x 7.48 gal/ft^3 = 448,800 gal

    $$\text{D.T., min} = \frac{\text{Vol, gal}}{\text{Flow, gpm}} = \frac{448{,}800\ \text{gal}}{3194.24\ \text{gpm}} = 140.50\ \text{min} \times (1\ \text{hr}/60\ \text{min}) = \mathbf{2.34\ hours}$$

Fluoridation

24. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 270,000 gallons of water. The raw water has a natural fluoride content of 0.4 mg/L and the desired fluoride in the finished water is 1.2 mg/L. How many gallons of feed solution is needed?

    Dose (mg/L) = 1.2 mg/L - 0.4 mg/L
    Dose (mg/L) = 0.8 mg/L

    $$\text{Feed Rate (gpd)} = \frac{\text{Dose (mg/L)} \times \text{Capacity (gpd)}}{18{,}000\ \text{mg/L}}$$

    $$\text{Feed Rate (gpd)} = \frac{0.8\ \text{mg/L} \times 270{,}000\ \text{gpd}}{18{,}000\ \text{mg/L}} = \frac{216{,}000}{18{,}000} = \mathbf{12\ gpd}$$

25. The natural fluoride level in the 1,156,000 gallons of water produced is 0.12 mg/L. The 55 gallon HFS day tank has a tare weight of 5 lbs. Seven gallons at 9.2 lbs. per gallon of the 28% HFS is being pumped daily into the clearwell. Calculate the fluoride dosage for your system.

    1,156,000 gal x (1 MG/1,000,000 gal) = 1.16 MGD

    7 gallons x 9.2 lbs/gal. = 64.4 lbs

    $$\text{Dose (mg/L)} = \frac{\text{Feed rate (lbs/day)} \times \text{AFI} \times \text{chemical purity (decimal)}}{\text{Capacity (MGD)} \times (8.34\ \text{lbs/gal})}$$

    $$\text{Dose (mg/L)} = \frac{64.4\ \text{lbs} \times 0.28\ \text{purity} \times 0.792\ \text{AFI}}{1.16\ \text{MGD} \times 8.34\ \text{lbs/gal}} = \frac{14.28\ \text{mg/L}}{9.67} = \mathbf{1.48\ mg/L}$$

26. Your EW-80 indicates an average of 6.3 pounds per day of granular sodium fluoride has been added to the average of 150,000 gallons of finished water for the last 30 days. What is the dose of fluoride in the water supply.

    150,000 gal x (1 MG/1,000,000 gal) = 0.15MGD

    $$\text{Dose (mg/L)} = \frac{\text{Feed rate (lbs/day) x AFI x chemical purity (decimal)}}{\text{Capacity (MGD) x (8.34 lbs/gal)}}$$

    $$\text{Dose (mg/L)} = \frac{\text{6.3 lbs x 0.453 AFI x 0.98 purity}}{\text{0.15 MGD x 8.34 lbs/gal}} = \frac{\text{2.80 mg/L}}{1.25} = \textbf{2.24 mg/L}$$

Pounds/Dosage

27. 0.0986 lb/min of soda ash is fed into 1,500,000 gal/day of treated water. What is the soda ash dosage?

    1,500,000 gal/day x (1 MG/1,000,000 gal) = 1.5 MGD

    0.0986 lb/min x (1440 min/1 day) = 141.98 lb/day

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 lb/gal
    = 141.98 lbs/day ÷ 1.5 MGD ÷ 8.34 lb/gal = **11.35 mg/L**

28. What is the dosage (of/where) 12 lbs of chlorine gas is added to 500,000 gallons of finished water?

    Q (MGD) = 500,000 gal/day x (1 MG/1,000,000 gal) = 0.5 MGD

    Dose (mg/L) = Feed (lb/day) ÷ Q (MGD) ÷ (8.34 lb/gal)
    = 12 lb/day ÷ 0.5 MGD ÷ 8.34 lb/gal = **2.88 mg/L**

29. The operator feeds 25% (W/W) liquid caustic soda to adjust the pH of the filtered water. The plant pumps 1.25 MGD and feeds the liquid at a constant rate of 27 ppm. The 25% caustic soda weighs 12 lbs per gallon. How much caustic soda by dry weight is fed in a day?

    Feed (lbs/day) = dose (mg/L) x flow (MGD) x 8.34 lbs/gal
    = 27 mg/L x 1.25 MGD x 8.34 lbs/gal = 281.48 lbs/day
    = 281.48 lbs/day x 0.25 = **70.37 lbs/day**

30. Determine the setting on a potassium permanganate chemical feed pump in pounds per day if the demand is determined to be 2.2 ppm, the desired permanganate residual is 0.4 ppm and the flow is 0.5 MGD.

    Dose (mg/L) = Demand (mg/L) + Residual (mg/L)
    Dose (mg/L) = 2.2 mg/L + 0.4 mg/L
    Dose (mg/L) = 2.6 mg/L

    Feed (lb/day) = Dose (mg/L) X Q (MGD) X (8.34 lb/gal)
    Feed (lb/day) = (2.6 mg/L) (0.5 MGD) (8.34 lb/gal) = **10.84 lb/day**

31. A system has a well that produces 250 gpm and a 1,500 gallon storage tank. There are 120 homes on the systems and the average daily consumption is 300 gallons/home. A chlorine dosage of 1.5 ppm is maintained using 65% HTH. How many pounds of HTH must be purchased each year?

    120 homes x 300 gallons/day/home = 36,000 gpd = 0.036 MGD

    $$\text{lbs/day} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{1.5 \text{ mg/L x } 0.036 \text{ MGD x } 8.34 \text{ lb/gal}}{0.65} = \frac{0.45 \text{ lb/day}}{0.65} = 0.69 \text{ lb/day}$$

    0.69 lbs/day x 365 days/year = **251.85 lbs/year**

32. How many pounds of HTH (65%) are needed to disinfect at 50 ppm a 10-inch diameter line that is 23,400 feet long?

    10 inch x (1 ft/12 inch) = 0.83 ft

    Volume = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 0.83 ft x 0.83 ft x 23,400 ft x 7.48 gal/ft^3 = 94,654.94 gal

    94,654.94 gal/day x (1 MG/1,000,000 gal) = 0.095 MGD

    $$\text{Feed (lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{50 \text{ mg/L x } 0.095 \text{ MGD x } 8.34 \text{ lb/gal}}{0.65} = \frac{39.62 \text{ lb/day}}{0.65} = \mathbf{60.95 \text{ lb/day}}$$

33. How many pounds of 65% HTH are needed to shock a 10 inch diameter pipe that is 1,980 feet long to 50 ppm of chlorine residual?

    10 inch x (1 ft/12 inch) = 0.83 ft

    Volume, gal = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 0.83 ft x 0.83 ft x 1,980 ft x 7.48 gal/ft^3 = 8,009.26 gal

    8,009.26 gal/day x (1 MG/1,000,000 gal) = 0.0080 MGD

    $$\text{Feed (lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{50 mg/L x 0.0080 MGD x 8.34 lb/gal}}{0.65} = \frac{\text{3.34 lb/day}}{0.65} = \textbf{5.14 lb/day}$$

34. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 1 to disinfect the tank. This method requires that the tank be filled to the overflow with enough chlorine added to the water to have a 10 mg/L residual in the tank after a 24 hour retention time. The tank holds 1,800,000 gallons filled to the overflow. It has been determined that the initial chlorine dose needs to be 25 mg/L. How many pounds of HTH 65% available chlorine will it take to get the required dose?

    $$\text{(lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{25 mg/L x 1.80 MGD x 8.34 lb/gal}}{0.65} = \frac{\text{375.3 lb/day}}{0.65} = \textbf{577.38 lb/day}$$

35. A treatment plant disinfects a flow of 0.9 MGD with 8.25% sodium hypochlorite to a dose of 2.0 mg/L. The sodium hypochlorite solution has a specific gravity of 1.8. How many gallons of sodium hypochlorite will the plant use per day?

    Weight of substance (lb/gal) = Sp. Gr. x weight of water (lb/gal)
    = 1.8 x 8.34 lb/gal = 15.01 lb/gal

    $$\text{(lb/day)} = \frac{\text{dose, mg/L x flow, MGD x 8.34 lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{\text{2.0 mg/L x 0.9 MGD x 8.34 lb/gal}}{0.0825} = \frac{\text{15.01 lb/day}}{0.0825} = \text{181.94 lb/day}$$

    gpd = 181.94 lb/gal x (1 gal/15.01 lb/gal) = **12.12 gpd**

36. A chlorine pump is feeding 12% bleach (1 gallon = 9.48 pounds) at a dosage of 2.0 mg/L. If 500,000 gallons are treated in 16 hours, how many gallons per hour is the pump feeding?
    525,000 gal/day x (1 MG/1,000,000 gal) = 0.53 MGD

    $$(\text{lb/day}) = \frac{\text{dose, mg/L} \times \text{flow, MGD} \times 8.34\ \text{lb/gal}}{\text{\%, as decimal}}$$

    $$= \frac{2.0\ \text{mg/L} \times 0.5\ \text{MGD} \times 8.34\ \text{lb/gal}}{0.12} = \frac{8.34\ \text{lb/day}}{0.12} = 69.5\ \text{lb/day}$$

    g/hr = 69.5 lb/gal x (1 gal/9.48 lb/gal) = 7.33 gpd x (1day/16 hr) = **0.46 gal/hr**

Filtration/Backwash

37. A treatment plant with dual filters processes a flow of 0.65 MGD. If the filters are 8 feet wide by 10 feet in length, what is the filtration rate?

    0.65 MGD x (694.4 gpm/1 MGD) = 451.36 gpm

    Area, ft^2 = length, feet x width, feet = 8 ft x 10 ft = 80 ft^2

    $$\text{Flow, gpm} = \frac{\text{flow, gpm}}{\text{\# of filters}} = \frac{451.36\ \text{gpm}}{2} = 225.68\ \text{gpm}$$

    $$\text{Filtration Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{225.68\ \text{gpm}}{80\ ft^2} = \mathbf{2.82\ gpm/ft^2}$$

38. A treatment plant with 4 sand filters treats a flow of 2.0 MG in 24 hours with two backwashes at the end of the run. If the filters are 10 feet wide by 20 feet in length, what is the loading rate on the filters in gpm/ft^2?

    2.0 MGD x (694.4 gpm/1 MGD) = 1,388.8 gpm

    Area, ft^2 = length, feet x width, feet = 10 ft x 20 ft = 200 ft^2

    $$\text{Flow, gpm} = \frac{\text{flow, gpm}}{\text{\# of filters}} = \frac{1{,}388.8\text{gpm}}{4} = 347.2\ \text{gpm}$$

    $$\text{Filtration Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{347.2\ \text{gpm}}{200\ ft^2} = \mathbf{1.74\ gpm/ft^2}$$

39. A filter that is 10 feet wide by 15 feet in length is backwashed for 3 minutes at a low rate of 1,200 gpm, then for 9 minutes at a high rate of 2,200 gpm and then at a low rate of 1,200 gpm for 3 minutes. What was the backwash run volume in gallons per square feet and the average flow rate in gpm/ft^2 ?

    Area, ft^2 = length, feet x width, feet = 10 ft x 15 ft = 150 ft^2

    Flow, gal = (6 min. x 1,200 gpm) + (9 min. x 2,200 gpm)
    = 7,200 gal + 19,800 gal = 27,000 gal

    $$\text{Backwash Vol, g/sq ft} = \frac{\text{Flow, gal}}{\text{Surface area, sq ft}} = \frac{27{,}000\text{ gal}}{150\text{ ft}^2} = 180\text{ gal/ft}^2$$

    Average flow rate, gpm/ft^2 = [180 gal/ft^2]/15 min = **12 gpm/ft^2**

40. Determine the backwash pumping rate in gpm for a filter 10 feet long by 10 feet wide if the backwash is 30 gpm per square foot?

    Area, ft^2 = length, feet x width, feet = 10 ft x 10 ft = 100 ft^2

    Backwash rate, gpm = Backwash rate, gpm/ft^2 x Area, ft^2
    = 30 gpm/ft^2 x 100 ft^2 = **3,000 gpm**

41. What percent of your total daily production of 500,000 gallons is used for backwash? The backwash ratio is 25 gpm per sq ft for 15 minutes each day through a filter that is 10 feet by 10 feet.

    Area, ft^2 = length, feet x width, feet = 10 ft x 10 ft = 100 ft^2

    Backwash Water, gal = Backwash Flow, gpm/ft^2 x Backwash Time, min x Area, ft^2
    = 25 gpm/ft^2 x 15 min x 100 ft^2 = 37,500 gal

    $$\text{Backwash \%} = \frac{\text{Volume, gal of Backwash}}{\text{Volume, gal total daily production}} \times 100\%$$

    $$\text{Backwash \%} = \frac{33{,}750\text{ gal}}{500{,}000\text{ gal}} \times 100\% = \mathbf{7.5\%}$$

Combination

42. You receive a bulk truckload of $NaOCl$ and the receiving slip states the net weight is 42,360 lbs. The certificate of analysis indicates the specific gravity is 1.22 and the trade % is 16. How many gallons of $NaOCl$ should you receive? If the quoted cost was \$0.75/gal., delivered, how much will you pay for the load? If you have two empty 2,100 gallon bulk tanks and a 300 gallon day tank with 120 gallons in it, will you be able to take the entire shipment?

    Weight of substance (lb/gal) = Sp. Gr. x weight of water (lb/gal)
    = 1.22 x 8.34 lb/gal = 10.18 lb/gal

    42,360 lbs x (1 gal/10.18 lbs)= **4,161.10 gal**

    4,161.10 gal x \$0.75 = **\$3,120.83**

    4,161.10 gal – {(2 x 2,100 gal) + (300 gal – 120 gal)}
    = 4,161.10 gal - (4,200 gal +180 gal) = 4,161.10 gal – 4,380 gal = **-218.90, Yes**

43. The liquid alum feed pump is set at 100% stroke and at 100% speed the pump will feed 77 gpd of solution. What speed should the pump setting be if the plant produces 3.2 MGD? The liquid alum is being dosed from the jar tests results at 8 mg/L. The liquid alum delivered to the plant contains 5.36 pound of alum per gallon of liquid solution.

    Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal)
    = 8 mg/L x 3.2 MGD x 8.34 lbs/gal = 213.50 lbs/day

    213.50 lbs/day x (1 gal/5.36 lbs) = 39.83 gpd

    $$\frac{A1}{A2} = \frac{B1}{B2} \quad \frac{A1}{39.83\ \text{gpd}} = \frac{100\%}{77\ \text{gpd}}. \quad A1 = \frac{100\% \times 39.83\ \text{gpd}}{77\ \text{gpd}} = \frac{3{,}983\%}{77} = \mathbf{51.73\%}$$

44. Due to flooding in the area, the City of Bedrock is in short supply of their 5.25% hypochlorite solution. They have contacted Flintstone PSD and asked to borrow enough 15.3% hypochlorite solution to produce 600 gallons of a 5.25% solution. Determine how many gallons of water and 15.3% hypochlorite are required to produce the desired percentage. The 750 gallon day tank has a diameter of 5 feet and is 25 feet tall. The 15.3% hypochlorite solution has a specific gravity of 1.28.

    $$\frac{A1}{A2} = \frac{B1}{B2} \quad \frac{A1}{5.25\ \%} = \frac{600\ \text{gal}}{15.3\%}. \quad A1 = \frac{600\ \text{gal} \times 5.25\%}{15.3\%} = \frac{3{,}150\ \text{gal}}{15.3} = \mathbf{205.88\ gal}$$

    206 gallons of 15.3% and 394 gallons of water

45. What is the dosage in mg/L, when 5 gph of a 5.25% hypochlorite solution is fed into a flow of 450 gpm? One gallon of hypochlorite weighs 9.02 pounds.

    lb/day = 5 gph x (24 hr/1 day) x (9.02lb/1 gal) = 1,082.4 gpd
    = 1,082.4 gpd x 0.0525 = 56.83 lb/day

    flow = 450 gpm x (1 MGD/694.4 gpm) = 0.65 MGD

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 #/gal
    = 56.83 lbs/day ÷ 0.65 MGD ÷ 8.34 #/gal = **10.48 mg/L**

46. During a one-week time period, the water meter indicated that 2,289,000 gallons of water were pumped. A two percent sodium hypochlorite solution is stored in a three-foot diameter plastic tank and stored in a nearby room is a partially filled one-hundred pound chlorine cylinder. During this one-week period, the level of hypochlorite in the tank dropped 2 feet 8 inches. Calculate the chlorine dose assuming the one-hundred pound cylinder has sixty pounds remaining in the cylinder?

    2 ft 10 inch = {(2 ft x (12 in/1ft) + 10 in} = (24 in + 10 in) = 34 in
    34 in x (1 ft/12 in) = 2.67 ft

    Hypochlorite, gal = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 3 ft x 3 ft x 2.67 ft x 7.48 gal/ft^3 = 141.1 gal

    Hypochlorite, lbs/day = 141.1 gal x (8.34 lb/1 gal) = 1,176.77 lb
    = 1,176.66 lb x 0.02 = 23.54 lb

    Flow, MGD = 2,289,000 gal x (1 MGD/1,000,000 gal) = 2.29 MGD

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 lb/gal
    = 23.54 lbs/day ÷ 2.29 MGD ÷ 8.34 lb/gal = **1.23 mg/L**