

ADVANCED MATH HANDBOOK

For Class III & IV Water Operators



2009

ADVANCED MATH HANDBOOK

Overview

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

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INTRODUCTION

Why is operator math necessary? It is needed to evaluate how well a plant is performing, or what the plant is capable of treating adequately. State authorities consider the topic important enough to include at least a little math on even the lowest level certification exams because solving these problems can help answer:

- Is the plant performing satisfactorily?
- Why is the effluent not meeting permit limits?
- Are various units adequately sized for their respective flow or organic load?
- Is the entire plant overloaded?
- Does the plant have plenty of reserve capacity?
- Would treatment be adequate if a clarifier were taken out of service?
- What amount of sludge should be wasted?
- What should be the setting on a chemical feed pump?

A certified operator is a professional operator and, as a professional, should be capable of mastering the math portion of the profession. Everything in a water treatment plant -- from pumps to chemical feed rates to adequacy of design -- can be determined with basic arithmetic. Learning the math does not have to be difficult.

1. Watch what you tell yourself.

Many times operators have said, "I'm dumb in math" or "I just can't pass the Class III exam."

This is a destructive form of self-talk and often turns out to be a self-fulfilling prophecy. On a subconscious level, these statements become a kind of core belief. You *can* do the math; it just takes practice and preparation. Self-confidence in any area is a matter of practice until you become proficient.

2. Attend operator training workshops and seminars.

These short courses usually have a math session. If you are counting on being proficient after one hour of workshop training, forget it. You need more practice. These training sessions, however, can be helpful in your basic understanding of operator math.

3. Obtain a good basic math book.

The best way to learn math is to study a little bit every day. Solve a problem every night after dinner. Can't get it? Keep working until you understand what you did wrong. Making a habit of daily study is the true road to proficiency.

4. Do a good job of preparation.

If you are taking a certification exam, begin studying several weeks ahead of time. Be calm. Fear, anxiety, frustration, or anger will sabotage your thinking processes. Studying in advance will help you be much more confident.

These tips should help with the math you need for certification exams but, more importantly, they should help you with your basic understanding of plant processes.

The same advice is applicable to all areas of knowledge in water treatment and collection. Preparation is the key.

BC (before calculators)

In the late 1960s, the electronic calculator was not available and calculations were made using manual arithmetic operations. Many operators at that time were older and had been out of school for years or even decades. Pencil and paper calculations were difficult for them, as were the concepts of organic and hydraulic loading, flow, etc.

In our state, the Class III and Class IV exams had a few math problems that had to be solved manually. Calculation errors made correct answers fairly rare, but an operator could get partial credit for setting up the problem correctly. Even today, operators can get partial credit for showing each step of their work, which may be the difference between passing and failing.

After-calculator era

Calculators began to be widely available in the early 1970s, relieving operators of laborious manual calculations. A few more math problems were added to the exams and the exam format eventually went 100 percent to multiple choice/true-false. Exams could then be machine-graded. Math problems, however, were worth only one point. For problems with several steps, an operator could elect not to use his/her time on calculations and merely pick one of the answer choices and move on.

With the use of calculators another problem was noticed—operators tended to read the problem and immediately begin pushing buttons on the calculator, hoping to come up with something close to one of the answers. Logical organization of the problems was neglected by many exam candidates. Calculator or not, organization of the problem should be done before doing the calculations.

Computerized Operations

With the advent of SCADA systems and computerized operations, laboratory data is entered and the calculation made by the computer for many different parameters. Newer operators training in these facilities are not likely to learn or retain basic math concepts.

In summary, math has always been and will continue to be one of the hardest parts of the operator's training. The keys to success are preparation and practice. Many opportunities for advancement will become available as older operators retire. The person who prepares will be the one who advances in this great career field.

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CONVERSION FACTORS

1 foot = 12 inches	1 minute = 60 seconds	cfs = cubic feet per second
1 inch = 2.54 centimeters	1 hour = 60 minutes	gpm = gallons per minute
1 gallon = 8 pints	1 day = 86,400 seconds	gpd = gallon per day
1 gallon = 8.34 pounds	1 day = 1,440 minutes	MGD = million gallons per day
1 gallon = 3.785 liters	1 day = 24 hours	mg/L = milligrams per liter
1 liter = 1,000 milliliters	1 % = 10,000 ppm	ppm = parts per million
1 cubic foot = 7.48 gallons	1 mg/L = 1 ppm	psi = pounds per square inch
1 cfs = 448 gpm	1 cubic foot = 62.38 pounds	fps = feet per second
1 gpm = 1,440 gpd	1 cubic yard = 27 cubic feet	cu ft = ft ³ = cubic feet
1 MGD = 1.55 cfs	1 gallon = 8 pints	sq ft = ft ² = square feet
1 psi = 2.31 feet	1 MGD = 694.4 gpm	gpg = grains per gallon
1 foot = 0.433 psi	1 grain per gallon = 17.12 mg/L	
π (pi) = 3.14	454 grams per lb	

TEMPERATURE

$$\text{Fahrenheit (°F)} = (1.8 \times \text{°C}) + 32$$

$$\text{Celsius (°C)} = 0.56 \times (\text{°F} - 32)$$

CIRCUMFERENCE, AREA & VOLUME

$$\text{Circumference (C, ft)} = \pi \times \text{diameter (D, ft)}$$

$$\text{Area of a rectangle (A, sq ft)} = (\text{length, ft}) \times (\text{width, ft})$$

$$\text{Area of a circle (A, sq ft)} = 0.785 \times (\text{diameter, ft})^2$$

$$\text{Area of a circle (A, sq ft)} = \pi \times (\text{radius, ft})^2$$

$$\text{Volume of a rectangle (V, cu ft)} = (\text{length, ft}) \times (\text{width, ft}) \times (\text{height, ft})$$

$$\text{Volume of a rectangle (V, gal)} = (\text{length, ft}) \times (\text{width, ft}) \times (\text{height, ft}) \times 7.48 \text{ gal/cu ft}$$

$$\text{Volume of a cylinder (V, cu ft)} = 0.785 \times (\text{diameter, ft})^2 \times (\text{height, ft})$$

$$\text{Volume of a cylinder (V, gal)} = 0.785 \times (\text{diameter, ft})^2 \times (\text{height, ft}) \times 7.48 \text{ gal/cu ft}$$

CHLORINATION

$$\text{Chlorine dose (mg/L)} = \text{chlorine demand (mg/L)} + \text{chlorine residual (mg/L)}$$

$$\text{Total chlorine residual (mg/L)} = \text{free chlorine residual (mg/L)} + \text{combined chlorine residual (mg/L)}$$

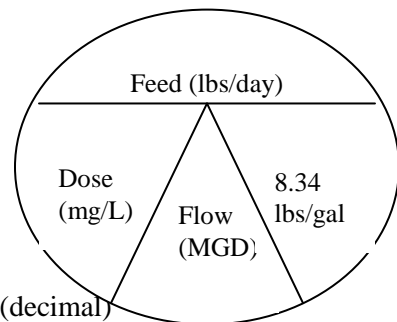
POUNDS, DOSAGE & FLOW

$$\text{Dose (mg/L)} = \text{Feed (lbs/day)} \div \text{flow (MGD)} \div (8.34 \text{ lbs/gal})$$

$$\text{Flow (MGD)} = \text{Feed (lbs/day)} \div \text{dose (mg/L)} \div (8.34 \text{ lbs/gal})$$

$$\text{Feed (lbs/day)} = \text{dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lbs/gal})$$

$$\text{Feed (lbs/day)} = \text{dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lbs/gal}) \div \% \text{ purity (decimal)}$$



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FLOW

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

Flow (Q, gps) = velocity (v, fps) x area (A, sq ft) x (7.48 gal/cu ft)

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

DETENTION TIME

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

PERCENT

Percent (%) = part ÷ whole x 100

Part = whole x percent ÷ 100

FLUORIDATION

$$\text{Fluoride Feed Rate (lbs/day)} = \frac{\text{Dose (mg/L)} \times \text{Capacity (MGD)} \times (8.34 \text{ lbs/gal})}{\text{Available Fluoride Ion (AFI)} \times \text{chemical purity (decimal)}}$$

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

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

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

Chemical	Formula	Available Fluoride Ion (AFI) Concentration	Chemical Purity
Sodium Fluoride	NaF	0.453	98%
Sodium Fluorosilicate	Na ₂ SiF ₆	0.607	98%
Fluorosilicic Acid	H ₂ SiF ₆	0.792	23%

MISC

Potassium Permanganate dose (mg/L) = 1(iron concentration mg/L) + 2(Manganese concentration mg/L)

$$\text{Alkalinity} = \frac{\text{mL of H}_2\text{SO}_4 \times 1,000}{\text{mL of sample}}$$

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

Horsepower:

$$Q \text{ (gpm)} = \frac{(3956) \times \text{HP}}{\text{Head (ft)} \times (\text{Sp. Grav})}$$

$$\text{HP} = \frac{\text{Voltage} \times \text{Current} \times \text{Efficiency}}{746}$$

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CHEMICAL DOSES

$$\text{Chemical Feed Setting (mL/min)} = \frac{(\text{Flow, MGD})(\text{Alum Dose, mg/L})(3.785\text{L/gal})(1,000,000 \text{ gal/MG})}{(\text{Liquid Alum, mg/mL})(24 \text{ hr/day})(60 \text{ min/hr})}$$

$$\text{Calibration of a Dry Chemical Feeder (lbs/day)} = \frac{\text{Chemical Applied, lbs}}{\text{Length of Application, day}}$$

Calibration of Solution

$$\text{Chemical Feeder (lbs/day)} = \frac{(\text{Chem Conc, mg/L})(\text{Vol pumped, mL})(1,440 \text{ min/day})}{(\text{Time pumped, min})(1,000 \text{ mL/L})(1,000 \text{ mg/g})(454 \text{ g/lb})}$$

FILTRATION

$$\text{Filtration Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}}$$

$$\text{Unit Filter Rate Volume (UFRV)} = (\text{Filtration Rate, gpm/sq ft})(\text{Filter Run, hr})(60 \text{ min/hr})$$

$$\text{Backwash Water, gal} = (\text{Backwash Flow, gpm})(\text{Backwash Time, min})$$

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

CORROSION CONTROL

$$\text{pH}_s = A + B + \log(\text{Ca}^{2+}) + \log(\text{Alk})$$

$$\text{Langlier Index} = \text{pH} - \text{pH}_s$$

COAGULATION AND FLOCCULATION

$$\text{Polymer, lbs} = \frac{(\text{Polymer Solution, gal})(8.34 \text{ lbs/gal})(\text{Polymer, \%})(\text{Sp Gr})}{100\%}$$

DISINFECTION

$$\text{Hypochlorite Flow, gpd} = \frac{(\text{Container area, sq ft})(\text{Drop, ft})(7.48 \text{ gal, cu ft})(24 \text{ hr/day})}{(\text{Time, hr})}$$

$$\text{Feed Rate, gal/day} = \frac{(\text{Feed Rate, lbs /day})(\text{Feed Dose, mg/L})}{\text{Feed Solution, mg/L}}$$

$$\text{Feed Rate, lbs/day} = \frac{\text{Feeder Setting, lbs/day}}{24 \text{ hr/day}}$$

$$\text{CT, mg/L-min} = \frac{(\text{Vol, gal})(T_{10})(\text{Free Chlorine Residual, mg/L})}{\text{Flow, gpm}}$$

$$\text{Free Chlorine Residual, mg/L} = \frac{(\text{CT, mg/L-min})}{T_{10}, \text{ min}}$$

PRACTICE EXAMS

The following pages contain the practice exams from the Class I and Class II Basic Math Handbook. These exams are a preliminary test to determine your baseline knowledge or preparedness for the advanced math questions included in this manual. If you are having problems with any of these calculations, please refer back to the Basic Math Handbook for more in depth instruction before proceeding with the Advanced Math Handbook.

CLASS I – MATH PRACTICE EXAM

1. A temperature measured 15°C is what in Fahrenheit?
 - a. 10°F
 - b. 40°F
 - c. 59°F
 - d. 75°F
2. Find a detention time in hours in of a tank that measures, 75 feet long by 50 feet wide and 20 feet deep with a flow to the tank of 2,000 gpm.
 - a. 0.6 hours
 - b. 4.7 hours
 - c. 282 hours
 - d. 434 hours
3. How many hours would it take to use the water in 200,000 ft. of 8 inch pipe with an outflow of 2,000 gpm and an inflow of 500 gpm?
 - a. 5.9 hours
 - b. 47 hours
 - c. 351 hours
 - d. 2,820 hours
4. What is the average fluoride reading over the past week: 0.8 mg/L, 0.75 mg/L, 0.84 mg/L, 1.22 mg/L, 0.98 mg/L, and 0.67 mg/L?
 - a. 0.66 mg/L
 - b. 0.75 mg/L
 - c. 0.88 mg/L
 - d. 1.05 mg/L
5. How many pounds of available chlorine are there in 50 pounds of 65% calcium hypochlorite?
 - a. 17.5 pounds
 - b. 32.5 pounds
 - c. 76.9 pounds
 - d. 142.8 pounds
6. Convert 8.8 grains per gallon to mg/L of hardness.
 - a. 0.51 mg/L
 - b. 15 mg/L
 - c. 151 mg/L
 - d. 511 mg/L

7. The pressure gauge on the discharge side of a pump reads _____ psi. The pressure is equivalent to 100 feet of head.
- 23 psi
 - 43 psi
 - 52 psi
 - 90 psi
8. The static pressure in a pipeline is 120 psi. How much head creates that much pressure?
- 51.9 feet
 - 60.0 feet
 - 277.2 feet
 - 900.4 feet
9. The elevation of water in the tank is at 1,500 feet, the elevation of the pump is 700 feet. What is the gauge pressure at the pump?
- 303 psi
 - 346 psi
 - 649 psi
 - 952 psi
10. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line that is 1,000 feet long using 50 mg/L chlorine solution?
- 0.6 gallons
 - 4.9 gallons
 - 7.5 gallons
 - 11.7 gallons
11. How much chlorine gas is required to treat 5 million gallons of water to provide a 0.7 residual?
- 2.9 pounds
 - 2.9 gallons
 - 29.2 pounds
 - 29.2 gallons
12. A chlorinator is set to feed 20 pounds of chlorine in 24 hours to a flow of 0.85 MGD. Find the chlorine dose in mg/L.
- 1.8 mg/L
 - 2.8 mg/L
 - 3.8 mg/L
 - 4.8 mg/L

13. What should be the setting on a chlorinator (lbs chlorine per 24 hours) if the service pump usually delivers 600 gpm and the desired chlorine dosage is 4.0 mg/L?
- 0.7 pounds
 - 8.7 pounds
 - 18.7 pounds
 - 28.7 pounds
14. In applying chlorine to water for disinfection, a dose of 8.34 pounds per million gallons is _____ mg/L?
- 1.00 mg/L
 - 1.50 mg/L
 - 4.33 mg/L
 - 8.34 mg/L
15. Calculate the dosage if your chlorinator is set to feed chlorine at 95 lbs into 4 MG?
- 2.85 mg/L
 - 28.5 mg/L
 - 285 mg/L
 - 0.285 mg/L
16. A flow of 1.5 MGD is _____ gpm?
- 62,500 gpm
 - 2,500 gpm
 - 1042 gpm
 - 694 gpm
17. Convert 10 mg/L to grains per gallon.
- 5.8 gpg
 - 0.58 gpg
 - 1.71 gpg
 - 10 gpg
18. A stream has a flow of 14 cfs. What is the mgd flow of the stream?
- 9.03 MGD
 - 0.37 MGD
 - 0.91 MGD
 - 4.33 MGD
19. What is the detention time (days) for a tank 50 ft. high & 40 ft. diameter & flow is 0.5 MGD?
- 9 days
 - 1.25 days
 - 0.24 MGD
 - 0.94 days

20. A tank is 25 ft long, 13 ft wide, and 20 ft high. What is the volume when the water level is at 12 ft.?
- a. 39,000 gal
 - b. 3,900 gal
 - c. 29,172 gal
 - d. 48,620 gal
21. How many pounds of 65% HTH chlorine will be required to disinfect 400 feet of 8-inch water main at 50 ppm?
- a. 0.68 lbs.
 - b. 6.8 lbs.
 - c. 0.43 lbs.
 - d. 5.0 lbs.
22. A plant uses 23 gallons of solution from its saturator in treating 220,000 gallons of water. What is the calculated dosage?
- a. 0.188 mg/L
 - b. 0.288 mg/L
 - c. 1.88 mg/L
 - d. 2.88 mg/L
23. A water plant produces 0.50 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?
- a. 0.28 gpd
 - b. 2.8 gpd
 - c. 28 gpd
 - d. 278 gpd

CLASS II – MATH PRACTICE EXAM

1. What is the pressure in psi at the bottom of a tank if the water level is at 34 feet?
 - a. 1.4 psi
 - b. 14.7 psi
 - c. 78.5 psi
 - d. 42 psi
2. Calculate the filtration rate in gpm/ft^2 for a filter with a surface length of 75 ft and a width of 17 ft when the applied flow is 2 MGD.
 - a. 0.12 gpm/ft^2
 - b. 10.7 gpm/ft^2
 - c. 2.40 gpm/ft^2
 - d. 1.08 gpm/ft^2
3. Convert 22 deg Fahrenheit to Celsius.
 - a. -5.6°C
 - b. 3.24°C
 - c. -10°C
 - d. 5.6°C
4. What should the chlorinator setting be (lbs/day) to treat a flow of 2 MGD if the chlorine demand is 5 mg/l and a chlorine residual of 0.8 mg/l is desired?
 - a. 42.33 lbs/day
 - b. 70.06 lbs/day
 - c. 96.74 lbs/day
 - d. 26.68 lbs/day
5. Calculate the filtration rate in gpm/ft^2 for a filter with dimensions of 60 ft X 25 ft when the applied flow is 1.3 MGD.
 - a. 8.67 gpm/ft^2
 - b. 0.30 gpm/ft^2
 - c. 1.60 gpm/ft^2
 - d. 0.60 gpm/ft^2
6. Convert 50 deg Celsius to Fahrenheit.
 - a. 22.4°F
 - b. 10.1°F
 - c. 122°F
 - d. 148°F

7. A flow of 2 MGD is treated with sodium fluorosilicate. The raw water contains 0.6 mg/l of fluoride and the desired fluoride concentration is 1.2 mg/l. What should the chemical feed rate in lbs/day be?
- 16.8 lbs/day
 - 50.5 lbs/day
 - 30.8 lbs/day
 - 26.6 lbs/day
8. A head of 20 ft equals a pressure of _____psi.
- 0.87 psi
 - 46.2 psi
 - 8.66 psi
 - 0.46 psi
9. How many pounds per day of HTH (65% available chlorine) are required to disinfect 10,000 feet of 8-inch water line if an initial dose of 20 mg/l is required?
- 6.77 lbs/day
 - 4.99 lbs/day
 - 4.35 lbs/day
 - 0.067 lbs/day
10. The pressure at the bottom of a tank is 28 pounds per square inch. How many feet of water would be in the tank?
- 74.6 ft
 - 1.21 ft
 - 12.1 ft
 - 64.7 ft
11. How much water is in a full system, if you have a clear well that has a diameter of 20 ft and is 50 ft. tall, and 56,000 ft of 6-inch water lines?
- 266,900 gal
 - 199,641 gal
 - 1,598,260 gal
 - 26,690 gal
12. There is a water tank at an elevation of 980 ft. and a house at an elevation of 550 ft. What is the pressure (psi) in the line feeding the house?
- 186 psi
 - 113 psi
 - 238 psi
 - 993 psi

13. Calculate the filtration rate in gpm/ft^2 for circular filter with a diameter of 20 ft and the applied flow is 1 MGD.
- 6.94 gpm/ft^2
 - 1.33 gpm/ft^2
 - 2.21 gpm/ft^2
 - 5.60 gpm/ft^2
14. What is the pumping rate in gpm, if you have a filter that is 50 ft long by 30 ft wide, and the filtration rate is 50 gpm per square foot?
- 1,500 gpm
 - 75,000 gpm
 - 33,000 gpm
 - 15,000 gpm
15. Convert a filter rate from 30 gpm/sq ft to inches per hour.
- 48 in/hr
 - 240 in/hr
 - 4 in/hr
 - 2887 in/hr
16. Calculate the dosage if your chlorinator is set to feed chlorine at 95 lbs into 4 MG?
- 2.85 mg/L
 - 28.5 mg/L
 - 285 mg/L
 - 0.285 mg/L
17. A flow of 1.5 MGD is _____ gpm?
- 62,500 gpm
 - 2,500 gpm
 - 1042 gpm
 - 694 gpm
18. Convert 10 mg/L to grains per gallon.
- 5.8 gpg
 - 0.58 gpg
 - 1.71 gpg
 - 10 gpg
19. A stream has a flow of 14 cfs. What is the MGD flow of the stream?
- 9.05 MGD
 - 0.37 MGD
 - 0.91 MGD
 - 4.33 MGD

20. What is the detention time (days) for a tank 50 ft. high & 40 ft. diameter & flow is 0.5 MGD?
- a. 9 days
 - b. 1.25 days
 - c. 0.24 MGD
 - d. 0.94 days
21. A tank is 25 ft long, 13 ft wide, and 20 ft high. The water level is at 12 ft. What is the volume?
- a. 39,000 gal
 - b. 3900 gal
 - c. 29,172 gal
 - d. 48,620 gal
22. How many pounds of 65% HTH chlorine will be required to disinfect 400 feet of 8-inch water main at 50 ppm?
- a. 0.67 lbs.
 - b. 6.7 lbs.
 - c. 0.43 lbs.
 - d. 5.0 lbs.

COAGULATION AND FLOCCULATION CALCULATIONS

Calculations are performed during operation of the coagulation and flocculation unit processes to determine chamber or basin volume, chemical feed calibration, chemical feeder settings, and detention time.

Chamber and Basin Volume Calculations

To determine the volume of a square or rectangular chamber or basin, we use:

$$\text{Volume (ft}^3\text{)} = \text{length (ft)} \times \text{width (ft)} \times \text{depth (ft)}$$

$$\text{Volume (gal)} = \text{length (ft)} \times \text{width (ft)} \times \text{depth (ft)} \times 7.48 \text{ gal/ft}^3$$

Example:

A flash mix chamber is 4 ft square with water to a depth of 3 ft. What is the volume of water (in gallons) in the chamber?

$$\begin{aligned}\text{Volume (gal)} &= \text{length (ft)} \times \text{width (ft)} \times \text{depth (ft)} \times 7.48 \text{ gal/ft}^3 \\ &= 4 \text{ ft} \times 4 \text{ ft} \times 3 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= \mathbf{359 \text{ gal}}\end{aligned}$$

Example:

A flocculation basin is 40 ft long and 12 ft wide and has water to a depth of 9 ft. What is the volume of water (in gallons) in the basin?

$$\begin{aligned}\text{Volume (gal)} &= \text{length (ft)} \times \text{width (ft)} \times \text{depth (ft)} \times 7.48 \text{ gal/ft}^3 \\ &= 40 \text{ ft} \times 12 \text{ ft} \times 9 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= \mathbf{32,314 \text{ gal}}\end{aligned}$$

Example:

A flocculation basin is 50 ft long, 22 ft wide and contains water to a depth of 11 ft 6 in. How many gallons of water are in the tank?

First convert the 6-inch portion of the depth measurement to feet:

$$6 \text{ in}/(12 \text{ in/ft}) = 0.5 \text{ ft}$$

$$\begin{aligned}\text{Volume (gal)} &= \text{length (ft)} \times \text{width (ft)} \times \text{depth (ft)} \times 7.48 \text{ gal/ft}^3 \\ &= 50 \text{ ft} \times 22 \text{ ft} \times 11.5 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= \mathbf{94,622 \text{ gal}}\end{aligned}$$

Detention Time

Because coagulation reactions are rapid, detention time for flash mixers is measured in seconds, whereas the detention time for flocculation basins is generally between 5 and 30 minutes. The equation used to calculate detention time is shown below.

$$\text{Detention time (min)} = \frac{\text{volume of tank (gal)}}{\text{flow rate (gpm)}}$$

Example:

Assume the flow is steady and continuous for a flash mix chamber 6 ft long and 4 ft wide with water to a depth of 3 ft. If the flow to the flash mix chamber is 6 MGD, what is the chamber detention time (in seconds)?

First, convert the flow rate from gpd to gps, so the time units will match:

$$6,000,000 / (1440 \text{ min/day} \times 60 \text{ sec/min}) = 69 \text{ gps}$$

$$\text{Detention time} = \frac{6 \text{ ft} \times 4 \text{ ft} \times 3 \text{ ft} \times 7.48 \text{ gal/ft}^3}{69 \text{ gps}}$$

$$= 7.8 \text{ sec}$$

SEDIMENTATION CALCULATIONS

Sedimentation, the separation of solids and liquids by gravity, is one of the most basic processes of water treatment. In water treatment, plain sedimentation, such as the use of a presedimentation basin for grit removal and sedimentation basin following coagulation-flocculation, is the most common.

Tank Volume Calculations

The two most common tank shapes of sedimentation tanks are rectangular and cylindrical.

For rectangular sedimentation tanks:

$$\text{Vol (gal)} = \text{length(ft)} \times \text{width (ft)} \times \text{depth (ft)} \times 7.48 \text{ gal/ft}^3$$

For cylindrical tanks:

$$\text{Vol (gal)} = 0.785 \times D^2 \times \text{depth (ft)} \times 7.48 \text{ gal/ft}^3$$

Detention Time

Detention time for basins varies from water system to water system. The equations used to calculate detention time:

$$\text{Detention time (hr)} = \frac{\text{volume of tank (gal)}}{\text{Flow rate (gph)}}$$

Surface Loading Rate

Surface loading rate measures only the water overflowing the process (plant flow only). Also known as surface overflow rate and surface settling rates.

Example:

A sedimentation basin that is 70 feet by 25 feet receives a flow of 1000 gpm. What is the surface loading rate in gpm/ft²?

$$\begin{aligned} \text{Surface loading rate} &= \frac{\text{flow (gpm)}}{\text{area (ft}^2\text{)}} \\ &= \frac{1000 \text{ gpm}}{70 \text{ ft} \times 25 \text{ ft}} \\ &= 0.6 \text{ gpm/ft}^2 \end{aligned}$$

Weir Loading Rate

Weir loading rate is the amount of water leaving the settling tank per linear foot of weir. Typically, weir loading rate is measured in flow (gpm) over each foot (ft) of weir.

$$\text{Weir loading rate (gpm/ft)} = \frac{\text{flow (gpm)}}{\text{Weir length (ft)}}$$

Example:

A rectangular sedimentation basin has a total of 115 ft of weir. What is the weir loading rate in gpm/ft² when the flow is 1,110,000 gpd?

$$\frac{1,110,000 \text{ gpd}}{1440 \text{ min/day}} = 771 \text{ gpm}$$

$$\text{Weir loading rate (gpm/ft)} = \frac{\text{flow (gpm)}}{\text{Weir length (ft)}}$$

$$= \frac{771 \text{ gpm}}{115 \text{ ft}}$$

$$= \mathbf{6.7 \text{ gpm/ft}}$$

CHEMICAL FEEDER CALCULATIONS

Determining Dry Chemical Feeder Setting (lb/day)

When adding (dosing) chemicals to the water flow, a measured amount of chemical is required that depends on such factors as the type of chemical used, the reason for dosing, and the flow rate being treated. To convert from mg/L to lb/day, the following equation is used:

$$\text{Chemical added (lb/day)} = \text{chemical dose (mg/L)} \times \text{flow (MGD)} \times 8.34 \text{ lb/gal}$$

Determining Chemical Solution Feeder Setting (gpd)

When solution concentration is expressed in lb chemical/gal solution, the required feed rate can be determined using the following equation:

$$\text{Chemical (lb/d)} = \text{Chemical dose (mg/L)} \times \text{flow (MGD)} \times 8.34 \text{ lb/day}$$

Then convert the lb/day dry chemical to gpd solution

$$\text{Solution feeder setting (gpd)} = \frac{\text{chemical (lb/day)}}{\text{lb chemical/gal solution}}$$

Determining Chemical Solution Feeder Setting (mL/min)

Some solution chemical feeders dispense chemical as milliliter per minute (mL/min). To calculate the mL/min solution required, use the following procedure:

$$\text{Feed rate (mL/min)} = \frac{\text{gpd} \times 3785 \text{ mL/gal}}{1440 \text{ min/day}}$$

The desired solution feed rate was calculated to be 9 gpd. What is this feed rate expressed as mL/min?

$$\text{Feed rate (mL/min)} = \frac{9 \text{ gpd} \times 3785 \text{ mL/gal}}{1440 \text{ min/day}}$$

$$= 24 \text{ mL/min}$$

Sometimes we will need to know mL/min solution feed rate but we will not know the gpd solution feed rate. In such cases, calculate the gpd solution feed rate first, using the following equation:

$$\text{Feed rate (gpd)} = \frac{\text{chemical (mg/L)} \times \text{flow (MGD)} \times 8.34 \text{ lb/gal}}{\text{Chemical (lb)/solution (gal)}}$$

CHEMICAL FEEDER CALIBRATIONS

Dry Chemical Feeder Calibration

Occasionally we need to perform a calibration calculation to compare the actual chemical feed rate with the feed rate indicated by the instrumentation. To calculate the actual feed rate for a dry chemical feeder, place a container under the feeder, weigh the container when empty, then weigh the container again after a specified length of time (e.g., 30 minutes). The actual chemical feed rate can be calculated using the following equation:

$$\text{Chemical feed rate (lb/min)} = \frac{\text{chemical applied (lb)}}{\text{Length of application (min)}}$$

If desired, the chemical feed rate can be converted to lb/d:

$$\text{Fed rate (lb/day)} = \text{feed rate (lb/min)} \times 1440 \text{ min/day}$$

Solution Chemical Feeder Calibration

As with other calibration calculations, the actual solution chemical feed rate is determined and then compared with the feed rate indicated by the instrumentation. To calculate the actual solution chemical feed rate, first express the solution feed rate in MGD. Once the MGD solution flow rate has been calculated, use the mg/L to determine chemical dosage in lb/d. If solution feed is expressed in mL/min, first convert the mL/min flow rate to a gpd flow rate:

$$\text{gpd} = \frac{\text{mL/min} \times 1440 \text{ min/day}}{3785 \text{ mL/gal}}$$

Then calculate chemical dosage, lb/day.

$$\text{Chemical (lb/day)} = \text{chemical dose (mg/L)} \times \text{flow (MGD)} \times 8.34 \text{ lb/day}$$

Example:

A calibration test was conducted for a solution chemical feeder. During a 5-minute test, the pump delivered 940 mg/L of the 1.20% polymer solution. What is the polymer dosage rate in lb/day? (Assume the polymer solution weighs 8.34 lb/gal).

The flow rate must be expressed in MGD; therefore, the mL/min solution flow rate must first be converted to gpd and then MGD. The mL/min flow rate is calculated as:

$$\frac{940 \text{ mL}}{5 \text{ min}} = 188 \text{ mL/min}$$

Next convert the mL/min flow rate to gpd flow rate:

$$\begin{aligned} \text{Flow rate} &= \frac{188 \text{ mL/min} \times 1440 \text{ min/day}}{3785 \text{ mL/gal}} \\ &= 72 \text{ gpd} \end{aligned}$$

Then calculate the lb/d polymer feed rate:

$$\begin{aligned} \text{Feed rate} &= 12,000 \text{ mg/L} \times 0.000072 \text{ MGD} \times 8.34 \text{ lb/day} \\ &= \mathbf{7.2 \text{ lb/day polymer}} \end{aligned}$$

CHEMICAL USAGE

Determining Chemical Dosage

One of the primary functions performed by water operators is the recording of data. Chemical use in lb/day or gpd is part of the data. From the data, the average daily use of chemicals and solutions can be determined. This information is important in forecasting expected chemical use by comparing it with chemicals in inventory and determining when additional chemicals will be required. To determine average chemical use, we use the following formulas:

$$\text{Average use (lb/day)} = \frac{\text{total chemical used (lb)}}{\text{Number of days}}$$

Or

$$\text{Average use (gpd)} = \frac{\text{total chemical used (gal)}}{\text{Number of days}}$$

Then we can calculate the number of days of supply in inventory:

$$\text{Day's supply in inventory} = \frac{\text{total chemical in inventory (lb)}}{\text{Average use (lb/day)}}$$

Or

$$\text{Day's supply in inventory} = \frac{\text{total chemical in inventory (gal)}}{\text{Average use (gpd)}}$$

FILTRATION RATE CALCULATIONS

Filtration Rate

One measure of filter production is filtration rate, which is the gallons per minute of water filtered through each square foot of filter area. Along with the filter run time, it provides valuable information for the operation of filters.

$$\text{Filter rate (gpm/ft}^2\text{)} = \frac{\text{flow rate (gpm)}}{\text{Filter surface area (ft}^2\text{)}}$$

Example:

A filter 18 feet by 22 feet receives a flow of 1750 gpm. What is the filtration rate in gpm/ft²?

$$\begin{aligned}\text{Filter rate (gpm/ft}^2\text{)} &= \frac{\text{flow rate (gpm)}}{\text{Filter surface area (ft}^2\text{)}} \\ &= \frac{1750 \text{ gpm}}{18 \text{ ft} \times 22 \text{ ft}} \\ &= \mathbf{4.4 \text{ gpm/ft}^2}\end{aligned}$$

Example:

A filter 45 feet long and 20 feet wide produces a total of 18 MG during a 76 hour filter run. What is the average filtration rate for the filter run (gpm/ft²)?

$$\begin{aligned}\text{Flow rate (gpm)} &= \frac{\text{total gallons produced}}{\text{Filter run (min)}} \\ &= \frac{18,000,000 \text{ gal}}{76 \text{ hr} \times 60 \text{ min/hr}} \\ &= \mathbf{3947 \text{ gpm}}\end{aligned}$$

Unit Filter Run Volume (UFRV)

The UFRV indicates the total gallons passing through each square foot of filter surface area during an entire filter run. This calculation is used to compare and evaluate filter runs. The UFRV will begin to decline as the performance of the filter begins to deteriorate.

$$\text{UFRV} = \frac{\text{total gallons filtered}}{\text{filter surface area (ft}^2\text{)}}$$

Example:

The total water filtered during a filter run (between backwashes) is 2,220,000 gallons. If the filter is 18 feet by 18 feet, what is the UFRV (gal/ft²)?

$$\text{UFRV} = \frac{\text{total gallons filtered}}{\text{filter surface area (ft}^2\text{)}}$$

$$= \frac{2,220,000 \text{ gal}}{18 \text{ ft} \times 18 \text{ ft}}$$

$$= \mathbf{6852 \text{ gal/ft}^2}$$

Example:

The average filtration rate for a filter was determined to be 2.0 gpm/ft². If the filter run time was 4250 minutes, what is the unit filter run volume (gal/ft²)?

$$\begin{aligned} \text{UFRV} &= 2.0 \text{ gpm/ft}^2 \times 4250 \text{ min} \\ &= \mathbf{8500 \text{ gal/ft}^2} \end{aligned}$$

BACKWASH CALCULATIONS

Filter Backwash Rate

In filter backwashing, one of the most important operational parameters to be determined is the amount of water (in gallons) required for each backwash. This amount depends on the design of the filter and the quality of the water being filtered. The actual backwashing typically lasts 15 minutes and uses amounts of 1 to 5% of the flow produced.

Backwash Pumping Rate

The desired backwash pumping rate (gpm) for a filter depends on the desired backwash rate (gpm/ft²) and areas of the filter (ft²). The backwash pumping rate can be determined by:

$$\text{Backwash pumping rate (gpm)} = \text{desired backwash rate (gpm/ft}^2\text{)} \times \text{filter area (ft}^2\text{)}$$

Example:

A filter is 25 feet long and 20 feet wide. If the desired backwash rate is 22 gpm/ft². What is the backwashing pumping rate?

$$\begin{aligned}\text{Backwash pumping rate (gpm)} &= \text{desired backwash rate (gpm/ft}^2\text{)} \times \text{filter area (ft}^2\text{)} \\ &= 22 \text{ gpm/ft}^2 \times 25 \text{ ft} \times 20 \text{ ft} \\ &= \mathbf{11,000 \text{ gpm}}\end{aligned}$$

Percent Effluent Water Used for Backwashing

Along with measuring the filtration rate and filter run time, another aspect of filter operation that is monitored for filter performance is the percent of product water used for backwashing.

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

Example:

During a filter run, 18,100,000 gallons of water were filtered. If 74,000 gallons of this product water were used for backwashing, what percent of the product water was used for backwashing?

$$\begin{aligned}\text{Backwash water (\%)} &= \frac{\text{backwash water (gal)}}{\text{Filtered water (gal)}} \times 100 \\ &= \frac{74,000 \text{ gal}}{18,100,000 \text{ gal}} \times 100 \\ &= \mathbf{0.41\%}\end{aligned}$$

CHLORINATION CALCULATIONS

Breakpoint Chlorination Calculations

To produce a free chlorine residual, enough chlorine must be added to the water to produce what is referred to as breakpoint chlorination. When chlorine is added to natural waters, the chlorine begins combining with and oxidizing the chemicals in the water before it begins disinfecting. Although residual chlorine will be detectable in the water, the chlorine will be in the combined form with a weak disinfecting power. Adding more chlorine to the water at this point actually decreases the chlorine residual as the additional chlorine destroys the combined chlorine compounds. At this stage, water may have a strong swimming pool or medicinal taste and odor. Free chlorine has the highest disinfecting power. The point at which most of the combined chlorine compounds have been destroyed and the free chlorine states to form is the breakpoint.

Example:

A chlorinator setting is increased by 2 lbs/day. The chlorine residual before the increased dosage was 0.2 mg/L. After the increased chlorine dose, the chlorine residual was 0.5 mg/L. The average flow being chlorinated is 2.5 MGD. Is the water being chlorinated beyond the breakpoint?

Calculate the expected increase in chlorine residual.

$$\begin{aligned}\text{dose (mg/L)} &= \frac{\text{feed rate (lbs/day)}}{\text{flow (MGD)} \times 8.34 \text{ lb/gal}} \\ &= \frac{2 \text{ lbs/day}}{1.25 \text{ MGD} \times 8.34 \text{ lb/gal}} \\ &= 0.19 \text{ mg/L}\end{aligned}$$

Actual increase in residual is:

$$\begin{aligned}\text{Actual dose (mg/L)} &= \text{Dose (mg/L)} - \text{expected dose (mg/L)} \\ &= 0.5 \text{ mg/L} - 0.19 \text{ mg/L} \\ &= \mathbf{0.31 \text{ mg/L, YES}}\end{aligned}$$

LABORATORY CALCULATIONS

Titration

A titration involves the measured addition of a standardized solution, which is usually in a buret, to another solution in a flask or beaker. The solution in the buret is referred to as the “titrant” and is added to the other solution until there is a measurable change in the test solution in the flask or beaker. This change is frequently a color change as a result of the addition of another chemical called an “indicator” to the solution in the flask before the titration begins. The solution in the buret is added slowly to the flask until the change, which is called the “end point,” is reached. The entire process is the “titration”. The following are the two most common titrations performed in a water treatment plant.

Alkalinity

Alkalinity is a measure of the water’s capacity to neutralize acids. In natural and treated waters, alkalinity is the result of bicarbonates, carbonates, and hydroxides of the metals of calcium, magnesium, and sodium.

The alkalinity determination is needed when calculating chemical dosages used in coagulation and water softening. Alkalinity must also be known to calculate corrosivity and to estimate the carbonate hardness of water. Alkalinity is usually expressed in terms of calcium carbonate (CaCO₃) equivalent.

$$\text{Alkalinity (mg/L as CaCO}_3\text{)} = \frac{\text{mL of H}_2\text{SO}_4 \times 1,000}{\text{mL of sample}}$$

Example:

A 100 mL sample is titrated with 0.02 M H₂SO₄. The endpoint is reached when 6.8 mL of H₂SO₄. The alkalinity concentration is:

$$\text{Alkalinity (mg/L as CaCO}_3\text{)} = \frac{\text{mL of H}_2\text{SO}_4 \times 1,000}{\text{mL of sample}}$$

$$= \frac{6.8 \text{ mL} \times 1,000}{100}$$

$$= 68 \text{ mg/L}$$

Hardness

Hardness is caused primarily by the calcium and magnesium ions commonly present in water. Hardness may also be caused by iron, manganese, aluminum, strontium, and zinc if present in significant amounts. Because only calcium and magnesium are present in significant concentrations in most waters, hardness can be defined as the total concentration of calcium and magnesium ions expressed as the calcium carbonate (CaCO₃) equivalent. There are two types or classifications of water hardness: carbonate and noncarbonated. Carbonate hardness is due to calcium/magnesium bicarbonate and carbonate. Hardness that is due to calcium/magnesium sulfate, chloride, or nitrate is called noncarbonated hardness.

$$\text{Hardness (mg/L as CaCO}_3\text{)} = \frac{\text{mL of EDTA} \times 1,000}{\text{mL of sample}}$$

Example:

A 50 mL sample is titrated with 0.01 M EDTA. The endpoint is reached when 7.8 mL of EDTA have been added. The hardness concentration is:

$$\begin{aligned}\text{Hardness (mg/L as CaCO}_3\text{)} &= \frac{\text{mL of EDTA} \times 1,000}{\text{mL of sample}} \\ &= \frac{7.8 \text{ mL} \times 1,000}{50 \text{ mL}} \\ &= \mathbf{156 \text{ mg/L}}\end{aligned}$$

Potassium Permanganate Demand

In ground waters, permanganate is primarily used to help control iron, manganese, sulfides, and color. In surface water treatment plants, permanganate is applied primarily for taste/odor, manganese, and trihalomethane (THM) problems. The following equation assumes there are no other oxidizable compounds in the raw water. However, typical oxidizable compounds usually found include organic color, bacteria, and even hydrogen sulfide. Therefore, the actual dose may be higher.

$$\text{Potassium Permanganate dose (mg/L)} = 1(\text{Iron concentration mg/L}) + 2(\text{Manganese concentration mg/L})$$

Example:

Calculate the estimated KMnO_4 demand in mg/L for water with 1.4 mg/L of iron and 1.2 mg/L of manganese.

$$\begin{aligned}\text{Potassium Permanganate dose (mg/L)} &= 1(\text{Iron concentration mg/L}) + 2(\text{Manganese concentration mg/L}) \\ &= 1(1.4 \text{ mg/L}) + 2(1.2 \text{ mg/L}) \\ &= \mathbf{3.8 \text{ mg/L}}\end{aligned}$$

Specific Gravity

Specific gravity is a relationship of the liquid to water. A liquid that is heavier than water will have a specific gravity greater than one. If you know the weight per gallon of the liquid you can find the specific gravity of the material by dividing the weight per gallon by the weight of one gallon of water.

$$\text{Specific Gravity} = \frac{\text{weight per gallon}}{\text{weight of water/gallon}}$$

Example:

Find the specific gravity of a chemical that has weight per gallon of 10.6 pounds per gallon.

$$\text{Specific gravity} = \frac{10.6 \text{ pounds per gallon}}{8.34 \text{ pounds per gallon}} = \mathbf{1.27}$$

When you have a material and you know the specific gravity of the material you can easily calculate the weight per gallon of the material. In order to find the weight per gallon take the weight of one gallon of water times the specific gravity of the material.

$$\text{Weight per gallon} = 8.34 \text{ lbs/gal} \times \text{specific gravity}$$

Example:

Find the weight per gallon of a liquid that has specific gravity of 1.04.

$$\text{Weight per gallon} = 8.34 \text{ lbs/gal} \times 1.04 = \mathbf{8.67 \text{ lbs/gal}}$$

HORSEPOWER & PUMP EFFICIENCY

Calculations for pump horsepower and efficiency are used in many water transmission, treatment, and distribution operations. Selecting a pump or combination of pumps with adequate pumping capacity depends on required flow rate and the effective height or total feet of head the pump must work against.

Horsepower

Horsepower (hp)

$$1\text{hp} = 33,000 \text{ ft-lb/min}$$

Horsepower is a combination of work and time. Work is defined as the operation of a force over a specific distance. For example, lifting a one-pound object one foot is measured as one foot-pound (ft – lb) per minute.

An example of one formula for calculating work is.

$$(\text{Head, ft})(\text{Flow Rate, lbs/min}) = \text{Power, ft-lbs/min}$$

Water Horsepower (whp)

Water Horsepower is the amount of horsepower required to lift water. A formula for calculating water horsepower is:

$$\text{whp} = \frac{(\text{Flow Rate, gpm})(\text{Total Head, ft})}{3,960}$$

Example:

A pump must pump 1,500 gallons per minute against a total head of 30 feet. What water horsepower is required to do the work?

Formula:

$$\text{whp} = \frac{(\text{Flow Rate, gpm})(\text{Total Head, ft})}{3,960}$$

$$\text{whp} = \frac{(1500 \text{ gpm})(30 \text{ ft})}{3,960}$$

$$\text{whp} = 11.36 \text{ hp}$$

Note: dividing by 3,960 in the first line of the formula is derived by converting gallons per minute to foot pounds per minute and then dividing by 33,000 foot pounds per minute to calculate horsepower.

Efficiency

The previous sample problem does not take into account that a motor, driven by electric current, is required to drive a pump to do the work. Neither the pump nor motor are ever 100 percent efficient due to friction. Not all the power supplied by the motor to the pump (brake horsepower) is used to lift the water (water horsepower). Not all electric current driving the motor (motor horsepower) is used to drive the pump.

Pumps usually fall between 50-85 percent efficiency and motors are generally between 80-95 percent efficient. These efficiency ratings are provided in manufacturer's information.

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

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

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

Example:

In the previous sample problem a pump must pump 1,500 gallons per minute against a total head of 30 feet. Water Horsepower required was calculated to be 11.36. But this does not take into account motor and pump efficiencies. Suppose that the motor efficiency is 85 percent and the pump efficiency is 90 percent. What would the horsepower requirement be?

$$\text{Horsepower} = \frac{\text{Water Horsepower}}{(\text{Pump Efficiency})(\text{Motor Efficiency})}$$

$$\text{Horsepower} = \frac{11.36}{(.85)(.90)}$$

$$\text{Horsepower requirement} = \mathbf{14.85}$$

Example:

If 11 kilowatts (kW) of power is supplied to a motor, and the brake horsepower is known to be 13, what is the efficiency of the motor?

$$1 \text{ Horsepower} = 0.746 \text{ kilowatts power}$$

Convert kilowatts to horsepower.

$$\text{Horsepower} = \frac{11 \text{ kilowatts}}{0.746 \text{ kW/hp}}$$

$$\text{Horsepower} = 14.75 \text{ hp}$$

Calculate the percentage efficiency of the motor.

$$\text{Percent efficiency} = \frac{\text{hp output}}{\text{hp supplied}} \times 100$$

$$\text{Percent efficiency} = \frac{13}{14.75} \times 100$$

$$\text{Percent efficiency} = \mathbf{88\%}$$

Pumping Costs

If the motor horsepower needed for a pumping job is 22 hp, and the cost for power is \$0.08 per kW/hr, what is the cost of operating the motor for two hours?

Convert horsepower to kilowatts.

$$\text{Kilowatts} = (22 \text{ hp})(0.746 \text{ kW/hp})$$

$$\text{Kilowatts} = 16.4 \text{ kW}$$

Multiply kilowatts by time.

$$16.4 \text{ kW} \times 2 \text{ hrs} = 32.8 \text{ kW-hrs}$$

Multiply kW-hrs by cost.

$$32.8 \text{ kW-hrs} \times \$0.08 \text{ per kW-hrs} = \$2.62$$

Total cost for two hours operating time is **\$2.62**

WIRE-TO-WATER CALCULATIONS

The term wire-to-water refers to the conversion of electrical horsepower to water horsepower. The motor takes electrical energy and converts it into mechanical energy. The pump turns mechanical energy into hydraulic energy. The electrical energy is measured as motor horsepower (MHP.) The mechanical energy is measured as brake horsepower (BHP.) And the hydraulic energy is measured as water horsepower (WHP.)

Horsepower is measured by lifting a weight a given distance in a specific time period. One horsepower is the amount of energy required to produce 33,000 ft-lbs of work per minute. That means that lifting 33,000 pounds one foot in one minute or lifting one pound 33,000 feet in the air in one minute would both require one horsepower worth of energy.

When water is pumped, performance is measured in flow (gallons/minute) and pressure (feet of head). If you multiply gallons per minute and feet of head the resulting units would be gallon-feet per minute. Multiply gallon-feet per minute by 8.34 pounds/gallon and the units become footpounds (of water) per minute. This can now be converted to water horsepower by dividing by 33,000 ft-lbs/min per horsepower.

$$\text{Gpm} \times 8.34 \times \text{Feet of Head} = \text{Water Horsepower (WHP)} \\ 33,000 \text{ ft-lbs/min/Hp}$$

This equation can be further simplified to:

$$\frac{\text{Gpm} \times \text{Feet of Head}}{3960} = \text{Water Horsepower (WHP)}$$

Brake horsepower is the amount of energy that must go into the pump to produce the required WHP. Losses due to friction and heat in the pump reduce the pump's efficiency and require more energy in than goes out. If a pump is 80% efficient, it requires 10 BHP to generate 8 WHP.

$$\text{BrakeHp} = \text{WaterHp}$$

Pump Efficiency

Motor horsepower is the amount of electrical energy that must go into the motor to produce the required BHP. Losses due to friction and heat in the motor reduce the motor's efficiency and require more energy in than goes out. If a motor is 88% efficient, it requires 10 BHP to generate 8.8 BHP

$$\text{MotorHp} = \frac{\text{BrakeHp}}{\text{Motor Eff}}$$

OR

$$\text{MotorHp} = \frac{\text{WaterHp}}{\text{Motor Eff} \times \text{Pump Eff}}$$

Motor horsepower can be converted into kilowatts by multiplying by 0.746 kW/Hp. Kilowatt-hours can be determined by multiplying kilowatts by run time in hours.

$$\text{MotorHp} \times 0.746 \text{ kW/Hp} \times \text{Hours} = \text{kW-Hours of electricity}$$

The following example has seven problems that relate to wire-to-water calculations. Each problem will take the calculation one step further. It is intended to show how the steps are linked, not to represent an example of a set of exam questions. An actual exam question would possibly require the calculation of water horsepower or calculation of cost of operation.

Pump Data: 6 Feet - Negative Suction Head

96 Feet - Discharge Head

17 Feet - Friction Loss

400 gpm - Flow

Motor Efficiency - 90%

Pump Efficiency - 80%

1. What is the static head on the pump?

$$96 \text{ ft} + 6 \text{ ft} = \mathbf{102 \text{ ft}}$$

2. What is the total dynamic head?

$$96 \text{ ft} + 6 \text{ ft} + 17 \text{ ft} = \mathbf{119 \text{ ft TDH}}$$

3. What is the Water Horsepower that the pump delivers?

$$\frac{400 \text{ gpm} \times 119 \text{ ft}}{3960} = \mathbf{12 \text{ WHp}}$$

4. What is the Brake Horsepower?

Change 80% to a decimal = 0.80

Find Brake Horsepower

$$12 \text{ Whp} = \mathbf{15 \text{ BHp}}$$

0.80 Pump Eff

5. What is the Motor Horsepower?

Change 90% to a decimal = 0.90

Find Motor Horsepower

$$15 \text{ BHp} = \mathbf{16.7 \text{ MHp}}$$

0.90 Motor Eff

6. How many Kilowatts of electricity does the motor require?

$$6.7 \text{ MHP} \times 0.746 \text{ Kw/HP} = \mathbf{12.5 \text{ Kw}}$$

7. If the pump runs 13 hours a day and electric rates are \$0.09/kW-Hour, How much does it cost to run the pump for a month (30 days)?

Find kW-Hours per day

$$12.5 \text{ kW} \times 13 \text{ hours/day} = 162 \text{ kW-Hours/day}$$

Find cost per day

$$162 \text{ kW-Hours} \times \$0.09/\text{kWHour} = \$14.58/\text{day}$$

Find cost for the month

$$14.58/\text{day} \times 30 \text{ days/month} = \mathbf{\$437.40/\text{month}}$$

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 is the total pay that the employee should receive?

$$\begin{aligned}\text{Overtime hours} &= \text{Total hours} - \text{Regular hours} \\ &= 52 \text{ hours} - 40 \text{ hours} \\ &= 12 \text{ hours (overtime)}\end{aligned}$$

$$\text{Regular pay} = 40 \text{ hours} \times \$17.50/\text{hour} = \$700.00$$

$$\text{Overtime wage} = \$17.50/\text{hour} \times 1.5 = \$26.25/\text{hour}$$

$$\text{Overtime pay} = 12 \text{ hours} \times \$26.25/\text{hour} = \$315.00$$

$$\begin{aligned}\text{Total pay} &= \text{Regular pay} + \text{Overtime pay} \\ &= \$700.00 + \$315.00 \\ &= \mathbf{\$1,015.00}\end{aligned}$$

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.

$$\text{Current salary} = \$650,000 \times 0.55 = \$357,500$$

$$\text{Other costs} = \$650,000 - \$357,500 = \$292,500$$

Calculate future salary costs.

$$\$357,500 \times 0.045 = \$16,087.50$$

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

Calculate future other costs.

$$\$292,500 \times 0.060 = \$17,550$$

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

$$\text{Total future budget costs} = \$373,587.50 + \$310,050 = \mathbf{\$683,637.50}$$

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?

$$\begin{aligned} \text{Time required to receive pipe after ordered} &= \text{Reserve period} + \text{Order period} \\ &= 12 \text{ weeks} + 6 \text{ weeks} = 18 \text{ weeks} \end{aligned}$$

$$\begin{aligned} \text{Minimum inventory} &= \text{Number of weeks} \times \text{Pipe required per week} \\ &= 18 \text{ weeks} \times 250 \text{ ft/week} = \mathbf{4,500 \text{ ft}} \end{aligned}$$

CLASS III – PRACTICE #1

1. A water system bills at a rate of \$0.40/1,000 gallons for the first 10,000 gallons; \$0.30/1,000 for the next 15,000 gallons; and \$0.15/1,000 gallons for all over 25,000 gallons. If a customer uses 35,000 gallons, how much is the water bill?
2. The total master meter reading for a system for one month was 44,413,296 gallons. The domestic meters total 19,396,413 gallons, the industrial meters total 8,256,497 gallons, and the purchased meters show a total of 6,989,235 gallons pumped. What percentage of total water was lost or unaccounted for?
3. A filter is 45 feet long and 20 feet wide. During a test of flow rate, the influent valve to the filter is closed for seven minutes. The water level drops 20 inches during this period. What is the filtration rate for the filter in gpm?
4. A 5-log removal of contaminants is expressed in terms of
5. How many pounds of HTH (70% available chlorine) would be necessary to disinfect 5,000 feet of 18-inch water main with 50 mg/L chlorine?
6. A clear well at a water plant is 30 feet wide by 25 feet long by 15 feet deep. What is the actual CT value of this tank if the free chlorine is 2.0 mg/L and the peak pumpage into the clear well is 0.75 MGD. Assume a T_{10} value of 10% based on a dye tracer study.
7. What is the minimum free chlorine residual required for the clear well to provide adequate disinfection if the required CT value is 18 mg/L-min and the T_{10} minimum detention time based on tracer studies is 30 minutes.
8. How many pounds of copper sulfate will be needed to dose a reservoir with 0.7 mg/L copper? The reservoir volume is 15 million gallons. The copper sulfate is 25%?
9. A 8-inch drop in 100 feet would be equal to :
10. A filter is 12 feet wide x 12 feet long x 8 feet deep. For a backwash rate of 10 gpm/ft², what backwash flow rate is needed?
11. What is the filtration rate for a filter bed 20 feet x 100 feet if the water level drops 16 inches in one minute?
12. The optimum level for fluoride in drinking water at your 0.45 MGD plant is 1.0 mg/L. Only trace amounts of fluoride naturally occur in your raw water. The daily analyzation result measures 1.02 mg/L. How many gallons of saturated (4 gram per 100 mL of water) NaF solution was pumped into the clearwell. A saturated solution contains an AFI of 0.452 and is 98% pure.

13. The optimum level alum dose from jar tests is 10 mg/L. Determine the setting on the liquid alum feeder in gallons per day when the flow is 0.65 MGD. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon solution.
14. A bucket placed under a dry chemical feeder weighed 0.6 pounds empty and 2.5 pounds after 30 minutes. The actual chemical feed rate in pounds per day is:
15. The liquid alum feed pump is set at 100% stroke and at a 100% speed the pump will feed 75 gpd of solution. What speed should the pump setting be if the plant produces 2.5 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 pounds of alum per gallon of liquid solution.
16. A customer reports a water leak near the bottom of the hill between your tank and the booster. Your SCADA records that the tank level and when your booster pumps kick on and off. Your tank is 50.5 feet in diameter and the base elevation is 800.5 feet and the overflow elevation is 877.9 feet. Your chart indicates the tank started losing water at 11:00 AM and you isolated the leak at 1:30 PM. The water level in the tank at 11:00 AM was 22.5 feet and at 1:30 PM the level was 19.2 feet. During the leak one pump was running in the booster station at a rate of 233 gpm. For this period you have determined your customers would normally use 12,000 gph.
17. You have a filter that measures 8 feet wide by 15 feet long. The media in the filter is standard filter sand with an anthracite cap. Your backwash pump has a maximum flow rate of 2,000 gpm. The freeboard above the media is 4 feet and the waste outlet on the filter is 10 inches in diameter. Your filter achieves 50% expansion at a backwash rate of 2,200 gpm. What is your optimum backwash rate in gpm/ft^2 ?

PRACTICE MATH - CLASS III #2

1. A water system bills at a rate of \$0.35/1,000 gallons for the first 10,000 gallons; \$0.25/1,000 for the next 15,000 gallons; and \$0.20/1,000 gallons for all over 25,000 gallons. If a customer uses 35,000 gallons, how much is the water bill?
2. The total master meter reading for a system for one month was 24,400,296 gallons. The domestic meters total 9,413,211 gallons, the industrial meters total 277,497 gallons, and the purchased meters show a total of 89,235 gallons pumped. What percentage of total water was lost or unaccounted for?
3. A filter is 33 feet long and 25 feet wide. During a test of flow rate, the influent valve to the filter is closed for seven minutes. The water level drops 18 inches during this period. What is the filtration rate for the filter in gpm?
4. A 4-log removal of contaminants is expressed in terms of
5. How many pounds of HTH (70% available chlorine) would be necessary to disinfect 10,000 feet of 12-inch water main with 50 mg/L chlorine?
6. A clear well at a water plant is 20 feet wide by 15 feet long by 25 feet deep. What is the actual CT value of this tank if the free chlorine is 3.5 mg/L and the peak pumpage into the clear well is 0.65 MGD. Assume a T_{10} value of 10% based on a dye tracer study.
7. What is the minimum free chlorine residual required for the clear well to provide adequate disinfection if the required CT value is 28 mg/L-min and the T_{10} minimum detention time based on tracer studies is 30 minutes.
8. How many pounds of copper sulfate will be needed to dose a reservoir with 0.65 mg/L copper? The reservoir volume is 12 million gallons. The copper sulfate is 25%?
9. A 9-inch drop in 100 feet would be equal to :
10. A filter is 10 feet wide x 12 feet long x 18 feet deep. For a backwash rate of 40 gpm/ft², what backwash flow rate is needed?
11. What is the filtration rate for a filter bed 30 feet x 70 feet if the water level drops 18 inches in two minute?
12. The optimum level for fluoride in drinking water at your 0.65 MGD plant is 1.0 mg/L. Only trace amounts of fluoride naturally occur in your raw water. The daily analyzation result measures 0.98 mg/L. How many gallons of saturated (4 gram per 100 mL of water) NaF solution was pumped into the clearwell. A saturated solution contains an AFI of 0.452 and is 98% pure.

13. The optimum level alum dose from jar tests is 7 mg/L. Determine the setting on the liquid alum feeder in gallons per day when the flow is 234,500 gpd. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon solution.
14. A bucket placed under a dry chemical feeder weighed 0.9 pounds empty and 5.3 pounds after 15 minutes. The actual chemical feed rate in pounds per day is:
15. The liquid alum feed pump is set at 100% stroke and at a 100% speed the pump will feed 80 gpd of solution. What speed should the pump setting be if the plant produces 1.0 MGD? The liquid alum is being dosed from the jar tests results at 12 mg/L. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon of liquid solution.
16. A customer reports a water leak near the bottom of the hill between your tank and the booster. Your SCADA records that the tank level and when your booster pumps kick on and off. Your tank is 45.5 feet in diameter and the base elevation is 650.5 feet and the overflow elevation is 767.9 feet. Your chart indicates the tank started losing water at 11:00 AM and you isolated the leak at 1:30 PM. The water level in the tank at 11:00 AM was 33.5 feet and at 1:30 PM the level was 29.2 feet. During the leak one pump was running in the booster station at a rate of 255 gpm. For this period you have determined your customers would normally use 11,300 gph.
17. You have a filter that measures 10 feet wide by 15 feet long. The media in the filter is standard filter sand with an anthracite cap. Your backwash pump has a maximum flow rate of 2,000 gpm. The freeboard above the media is 4 feet and the waste outlet on the filter is 8 inches in diameter. Your filter achieves 50% expansion at a backwash rate of 2,400 gpm. What is your optimum backwash rate in gpm/ft²?

CLASS IV – PRACTICE #1

Use the following information to answer questions 1-5. Your water treatment plant uses potassium permanganate to oxidize iron and manganese from the raw water. The plant processes are traditional, complete treatment with greensand filters.

potassium permanganate dose = $\{2 \times (\text{raw Mn, mg/L})\} + \text{raw Fe, mg/L} + \text{desired residual}$

potassium permanganate in inventory = 15,000 lbs.

calibration beaker weight = 450 g

plant flow = 2.9 MGD

raw water manganese = 2.8 mg/L

raw water iron = 0.6 mg/L

chemical supplier does not work on Saturday or Sunday

a single bulk delivery cannot exceed 48,000 lbs

desired permanganate residual = 0.1 mg/L

price for a full bulk delivery = \$3,520.00/ton

time required from order to delivery = 10 working days

price for deliveries under 12,000 lbs = \$3,250.00/ton

Dry Feeder Output per 15 minute grab sample

Setting	Sample weight including beaker
30%	775 grams
50%	992 grams
70%	1248 grams

1. What is your potassium permanganate dose in lbs/day?
2. What is the dry feeder calibration results?
3. What is the projected cost (to the nearest hundred) for potassium permanganate for a 12 month period?
4. How many days can you operate before you must place an order for a full bulk load?
5. If your daily flow changes to 3.3 MGD, what should your feeder setting be in %?
6. As the Chief Operator you have been asked by the Mayor and city council to provide them with a projected annual operating budget (rounded to the nearest \$100) for chlorination at a booster pump station.
DATA: The booster pumps run on a continuous 12 hour alternating cycle (both pumps identical). The pump is 150 HP, with an efficiency of 72%, pumping into a 18 inch D.I. pipe. The elevation of the pumps is 4,089 feet and the reservoir they are pumping to is 4,356 feet (floor). The tank is 155 feet in diameter with an overflow at 25 feet, above the floor. The chlorine demand is 1.0 mg/L with a required free chlorine residual 0.6 mg/L and the cost of chlorine is 47 cents per pound.

7. Your treatment plant is feeding a dry polymer mixed in a barrel with water and pumped to the injection point. You are mixing 2 lbs. into 500 gal. of water. From testing you have determined the dose needed to be 0.8 ppm. Your pump is calibrated to feed 35 L/min at 100% and you are currently treating 0.5 MGD. What should your pump setting be in % and L/min?
8. 15% sodium hypochlorite yields 1.25 lbs of chlorine per gallon. The sodium hypochlorite delivered to you has a certificate of analysis result and tests to be 14.2%. You are currently treating 2.08 MGD and your chlorine demand is 4.2 mg/L. Your sodium hypochlorite pump is calibrated to feed 1.6 gpm at 100% speed setting. You want an effluent chlorine residual of 1.5 mg/L. What should your sodium hypochlorite pump speed setting be in %?
9. A rectangular sedimentation basin is 40 feet long, 55 feet wide, 18 feet deep and treats a flow of 2.4 MGD. Determine the loss in detention time in minutes if the basin contains 7 feet of sludge.
10. Liquid alum delivered to a water plant contains 547.8 mg/mL of liquid solution. Jar tests indicate that the best alum dose is 5 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the flow is 1.95 MGD.
11. A reaction basin 12 ft. in diameter and 14 ft. deep was added to the existing basin 35 ft. in diameter and 10 ft. deep. What is the maximum flow in MGD that will allow a 30 minute detention time?
12. Your water system is required to take 30 first-draw samples for lead. The lab analysis shows the following:

3 samples at 0.005 mg/L	2 sample at 0.030 mg/L
1 samples at 0.010 mg/L	6 samples at 0.017 mg/L
3 samples at 0.015 mg/L	9 samples at <0.002 mg/L
1 sample at 0.020 mg/L	4 samples at 0.007 mg/L
1 sample at 0.025 mg/L	

What is the 90th percentile of the lead level?

13. A polymer pump is calibrated by timing to deliver 650 mL in 30 seconds. How much coagulant is being added in gpm?

CLASS IV – PRACTICE #2

Use the following information to answer the following questions. Your water treatment plant uses potassium permanganate to oxidize iron and manganese from the raw water. The plant processes are traditional, complete treatment with greensand filters.

potassium permanganate dose = $\{2 \times (\text{raw Mn, mg/L})\} + \text{raw Fe, mg/L} + \text{desired residual}$

potassium permanganate in inventory = 21,000 lbs.

calibration beaker weight = 450 g

plant flow = 3.9 MGD

raw water manganese = 1.6 mg/L

raw water iron = 0.6 mg/L

chemical supplier does not work on Saturday or Sunday

a single bulk delivery cannot exceed 35,000 lbs

desired permanganate residual = 0.1 mg/L

price for a full bulk delivery = \$3,220.00/ton

time required from order to delivery = 10 working days

price for deliveries under 12,000 lbs = \$3,000.00/ton

Dry Feeder Output per 15 minute grab sample

Setting	Sample weight including beaker
30%	775 grams
50%	992 grams
70%	1248 grams

1. What is your potassium permanganate dose in lbs/day?
2. What is the dry feeder calibration results? (setting in %)
3. What is the projected cost (to the nearest hundred) for potassium permanganate for a 12 month period?
4. How many days can you operate before you must place an order for a full bulk load?
5. If your daily flow changes to 2.9 MGD, what should your feeder setting be in %?
6. As the Chief Operator you have been asked by the Mayor and city council to provide them with a projected annual operating budget (rounded to the nearest \$100) for chlorination at a booster pump station.
DATA: The booster pumps run on a continuous 12 hour alternating cycle (both pumps identical). The pump is 125 HP, with an efficiency of 82%, pumping into a 18 inch D.I. pipe. The elevation of the pumps is 4118 feet and the reservoir they are pumping to is 4,356 feet (floor). The tank is 155 feet in diameter with an overflow at 25 feet, above the floor. The chlorine demand is 1.3 mg/L with a required free chlorine residual 0.6 mg/L and the cost of chlorine is 43 cents per pound.

7. Your treatment plant is feeding a dry polymer mixed in a barrel with water and pumped to the injection point. You are mixing 2.5 lbs. into 500 gal. of water. From testing you have determined the dose needed to be 0.75 ppm. Your pump is calibrated to feed 25 L/min at 100% and you are currently treating 0.45 MGD. What should your pump setting be in % and L/min?
8. 15% sodium hypochlorite yields 1.25 lbs of chlorine per gallon. The sodium hypochlorite delivered to you has a certificate of analysis result and tests to be 14.4%. You are currently treating 1.48 MGD and your chlorine demand is 3.2 mg/L. Your sodium hypochlorite pump is calibrated to feed 1.9 gpm at 100% speed setting. You want an effluent chlorine residual of 1.4 mg/L. What should your sodium hypochlorite pump speed setting be in %?
9. A rectangular sedimentation basin is 42 feet long, 45 feet wide, 28 feet deep and treats a flow of 1.97 MGD. Determine the loss in detention time in minutes if the basin contains 11 feet of sludge.
10. Liquid alum delivered to a water plant contains 357.8 mg/mL of liquid solution. Jar tests indicate that the best alum dose is 7 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the flow is 1.23 MGD.
11. A reaction basin 15 ft. in diameter and 16 ft. deep was added to the existing basin 15 ft. in diameter and 19 ft. deep. What is the maximum flow in MGD that will allow a 30 minute detention time?
12. Your water system is required to take 50 first-draw samples for lead. The lab analysis shows the following:

3 samples at 0.005 mg/L	2 sample at 0.030 mg/L
1 samples at 0.010 mg/L	6 samples at 0.017 mg/L
3 samples at 0.015 mg/L	9 samples at <0.002 mg/L
1 sample at 0.020 mg/L	4 samples at 0.007 mg/L
1 sample at 0.025 mg/L	

What is the 90th percentile of the lead level?

13. A polymer pump is calibrated by timing to deliver 456 mL in 25 seconds. How much coagulant is being added in gpm?

APPENDIX A - ANSWERS TO CLASS I – MATH PRACTICE EXAM

1. A temperature measured 15°C is what in Fahrenheit? **c. 59°F**

$$\begin{aligned} F &= (1.8 \times C) + 32 \\ &= (1.8 \times 15) + 32 \\ &= (27) + 32 \\ &= \mathbf{59^{\circ}F} \end{aligned}$$

2. Find a detention time in hours in of a tank that measures, 75 feet long by 50 feet wide and 20 feet deep with a flow to the tank of 2,000 gpm. **b. 4.7 hours**

$$\begin{aligned} \text{Vol} &= L \times W \times H \times 7.48 \text{ gal/ft}^3 \\ &= 75 \text{ ft} \times 50 \text{ ft} \times 20 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= 561,000 \text{ gal} \end{aligned}$$

$$\begin{aligned} \text{DT} &= \text{Vol (gal)}/\text{Flow (gpm)} \\ &= 561,000 \text{ gal}/2,000 \text{ gpm} \\ &= 280.5 \text{ min} \times 1 \text{ hour}/60 \text{ min} \\ &= \mathbf{4.7 \text{ hours}} \end{aligned}$$

3. How many hours would it take to use the water in 200,000 ft. of 8 inch pipe with an outflow of 2,000 gpm and an inflow of 500 gpm? **a. 5.9 hours**

$$8 \text{ in} \times 1 \text{ ft}/12 \text{ in} = 0.67 \text{ ft}$$

$$\begin{aligned} \text{Vol} &= 0.785d^2 h \times (7.48 \text{ gal/ft}^3) \\ &= 0.785 \times 0.67 \text{ ft} \times 0.67 \text{ ft} \times 200,000 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= 527,170 \text{ gal} \end{aligned}$$

$$\begin{aligned} \text{DT} &= \text{Vol (gal)}/[\text{outflow (gpm)} - \text{inflow (gpm)}] \\ &= 527,170 \text{ gal} \div [2,000 \text{ gpm} - 500 \text{ gpm}] \\ &= 527,170 \text{ gal} \div 1,500 \text{ gpm} \\ &= 351.4 \text{ min} \times 1 \text{ hour}/60 \text{ min} \\ &= \mathbf{5.86 \text{ hours}} \end{aligned}$$

4. What is the average fluoride reading over the past week: 0.8 mg/L, 0.75 mg/L, 0.84 mg/L, 1.22 mg/L, 0.98 mg/L, and 0.67 mg/L? **c. 0.88 mg/L**
Average = total/total number

$$\begin{aligned} &= \frac{(0.8 + 0.75 + 0.84 + 1.22 + 0.98 + 0.67) \text{ mg/L}}{6} \\ &= \frac{5.26 \text{ mg/L}}{6} \\ &= \mathbf{0.88 \text{ mg/L}} \end{aligned}$$

APPENDIX A - ANSWERS TO CLASS I – MATH PRACTICE EXAM (CONTINUED)

5. How many pounds of available chlorine are there in 50 pounds of 65% calcium hypochlorite? **b. 32.5 pounds**

$$\begin{aligned}\text{Part} &= \text{whole} \times \text{percent (as decimal)} \\ &= 50 \text{ pounds} \times 0.65 \\ &= \mathbf{32.5 \text{ pounds available chlorine}}\end{aligned}$$

6. Convert 8.8 grains per gallon to mg/L of hardness. **c. 151 mg/L**

$$8.8 \text{ gpg} \times (17.12 \text{ mg/L/1 gpg}) = \mathbf{150.66 \text{ mg/L}}$$

7. The pressure gauge on the discharge side of a pump reads _____ psi. The pressure is equivalent to 100 feet of head. **b. 43 psi**

$$100 \text{ ft} \times (1 \text{ psi}/2.31 \text{ ft}) = \mathbf{43.3 \text{ psi}}$$

8. The static pressure in a pipeline is 120 psi. How much head creates that much pressure? **c. 277.2 feet**

$$120 \text{ psi} \times (2.31 \text{ ft}/1 \text{ psi}) = \mathbf{277.2 \text{ ft}}$$

9. The elevation of water in the tank is at 1,500 feet, the elevation of the pump is 700 feet. What is the gauge pressure at the pump? **b. 346 psi**

$$1500 \text{ ft} - 700 \text{ ft} = 800 \text{ ft (difference)}$$

$$800 \text{ ft} \times (1 \text{ psi}/2.31 \text{ ft}) = \mathbf{346.3 \text{ psi}}$$

10. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line that is 1,000 feet long using 50 mg/L chlorine solution? **a. 0.6 gallons**

$$6 \text{ inch} \times (1 \text{ ft}/12 \text{ inch}) = 0.5 \text{ ft}$$

$$\begin{aligned}\text{Flow} &= 0.785d^2 h \times (7.48 \text{ gal/ft}^3) \\ &= 0.785 \times 0.5 \text{ ft} \times 0.5 \text{ ft} \times 1000 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= 1467.95 \text{ gal} \times (1\text{MG}/1,000,000 \text{ gal}) \\ &= 0.0014679 \text{ MG}\end{aligned}$$

$$\begin{aligned}\text{Feed (lbs/day)} &= \text{Dose (mg/L)} \times \text{Flow (MG)} \times 8.34 \text{ lb/gal} \\ &= 50 \text{ mg/L} \times 0.0014679 \text{ MG} \times 8.34 \text{ lb/gal} \\ &= 0.61 \text{ lbs / day}\end{aligned}$$

APPENDIX A - ANSWERS TO CLASS I – MATH PRACTICE EXAM (CONTINUED)

10. Feed (lbs/day) = 0.61 lbs ÷ Percent (as decimal)
= 0.61 lbs ÷ 0.125
= 4.88 lbs
= $(4.88 \cancel{\text{lbs}}) \times \frac{(1 \cancel{\text{gal}})}{(8.34 \cancel{\text{lbs}})}$
= **0.58 gallons**

11. How much chlorine gas is required to treat 5 million gallons of water to provide a 0.7 residual? **c. 29.2 pounds**

$$\begin{aligned}\text{Feed (lbs/day)} &= \text{Dose (mg/L)} \times \text{Flow (MGD)} \times 8.34 \text{ lbs/gal} \\ &= 0.7 \text{ mg/L} \times 5 \text{ MGD} \times 8.34 \text{ lbs/gal} \\ &= \mathbf{29.19 \text{ pounds}}\end{aligned}$$

12. A chlorinator is set to feed 20 pounds of chlorine in 24 hours to a flow of 0.85 MGD. Find the chlorine dose in mg/L. **b. 2.8 mg/L**

$$\begin{aligned}\text{Dose (mg/l)} &= \text{Feed (lbs/day)} / \text{Flow (MGD)} / 8.34 \text{ lbs/gal} \\ &= 20 \text{ lbs/day} / 0.85 \text{ MGD} / 8.34 \text{ lbs/gal} \\ &= \mathbf{2.82 \text{ mg/L}}\end{aligned}$$

13. What should be the setting on a chlorinator (lbs chlorine per 24 hours) if the service pump usually delivers 600 gpm and the desired chlorine dosage is 4.0 mg/L? **d. 28.7 lb/day**

$$600 \text{ gpm} \times (1 \text{ MG} / 694.4 \text{ gpm}) = 0.86 \text{ MG}$$

$$\begin{aligned}\text{Feed (lbs/day)} &= \text{Dose (mg/L)} \times \text{Flow (MGD)} \times 8.34 \text{ lb/gal} \\ &= 4.0 \text{ mg/L} \times 0.86 \text{ MGD} \times 8.34 \text{ lb/gal} \\ &= \mathbf{28.69 \text{ lb/day}}\end{aligned}$$

14. In applying chlorine to water for disinfection, a dose of 8.34 pounds per million gallons is _____ mg/L? **a. 1.00 mg/L**

$$\begin{aligned}\text{Dose (mg/l)} &= \text{Feed (lbs/day)} / \text{Flow (MGD)} / (8.34 \text{ lbs/gal}) \\ &= (8.34 \text{ lbs/gal}) / (1 \text{ MGD}) / (8.34 \text{ lbs/gal}) \\ &= \mathbf{1.00 \text{ mg/L}}\end{aligned}$$

15. Calculate the dosage if your chlorinator is set to feed chlorine at 95 lbs into 4 MG? **a. 2.85 mg/L**

$$\begin{aligned}\text{Dose (mg/l)} &= \text{Feed (lbs/day)} / \text{Flow (MGD)} / (8.34 \text{ lbs/gal}) \\ &= (95 \text{ lbs/day}) / (4 \text{ MGD}) / (8.34 \text{ lbs/gal}) \\ &= \mathbf{2.85 \text{ mg/L}}\end{aligned}$$

APPENDIX A - ANSWERS TO CLASS I – MATH PRACTICE EXAM (CONTINUED)

16. A flow of 1.5 MGD is _____ gpm? **c. 1042 gpm**

$$1.5 \text{ MGD} \times (694.4 \text{ gpm}/1 \text{ MGD}) = \mathbf{1041.6 \text{ gpm}}$$

17. Convert 10 mg/L to grains per gallon. **b. 0.58 gpg**

$$10 \text{ mg/L} \times (1 \text{ gpg}/17.12 \text{ mg/L}) = \mathbf{0.58 \text{ gpg}}$$

18. A stream has a flow of 14 cfs. What is the mgd flow of the stream? **a. 9.03 MGD**

$$14 \text{ cfs} \times (1 \text{ MGD}/1.55 \text{ cfs}) = \mathbf{9.03 \text{ MGD}}$$

19. What is the detention time (days) for a tank 50 ft. high & 40 ft. diameter & flow is 0.5 MGD? **d. 0.94 days**

$$\begin{aligned} \text{Volume} &= 0.785 \text{ d}^2 \text{ h} \times (7.48 \text{ gal/ft}^3) \\ &= 0.785 \times 40 \text{ ft} \times 40 \text{ ft} \times 50 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= 469,744 \text{ gal} \times (1 \text{ MG}/1,000,000 \text{ gal}) \\ &= 0.47 \text{ MG} \end{aligned}$$

$$\begin{aligned} \text{DT} &= \text{Vol (MG)} / \text{Flow (MGD)} \\ &= 0.47 \text{ MG} / 0.5 \text{ MGD} \\ &= \mathbf{0.94 \text{ days}} \end{aligned}$$

20. A tank is 25 ft long, 13 ft wide, and 20 ft high. What is the volume when the water level is at 12 ft.? **c. 29,172 gal**

$$\begin{aligned} \text{Volume} &= \text{L} \times \text{W} \times \text{H} \times 7.48 \text{ gal/ft}^3 \\ &= 25 \text{ ft} \times 13 \text{ ft} \times 12 \text{ ft} \times 7.48 \text{ gal/ft}^3 \\ &= \mathbf{29,172 \text{ gal}} \end{aligned}$$

APPENDIX A - ANSWERS TO CLASS I – MATH PRACTICE EXAM (CONTINUED)

21. How many pounds of 65% HTH chlorine will be required to disinfect 400 feet of 8-inch water main at 50 ppm? **a. 0.68 lbs**

$$8 \text{ inch} \times (1 \text{ ft}/12 \text{ inch}) = 0.67 \text{ ft}$$

$$\begin{aligned}\text{Volume} &= 0.785 \text{ d}^2 \text{ h} \times (7.48 \text{ gal}/\text{ft}^3) \\ &= 0.785 \times 0.67 \text{ ft} \times 0.67 \text{ ft} \times 400 \text{ ft} \times 7.48 \text{ gal}/\text{ft}^3 \\ &= 1054 \text{ gal} \times (1\text{MG}/1,000,000 \text{ gal}) \\ &= 0.001054 \text{ MG}\end{aligned}$$

$$\begin{aligned}\text{Feed (lbs/day)} &= \text{Dose (mg/L)} \times \text{Flow (MGD)} \times (8.34 \text{ lbs/gal}) \\ &= 50 \text{ mg/L} \times 0.001054 \text{ MGD} \times 8.34 \text{ lbs/gal} \\ &= 0.43 \text{ lbs/day}\end{aligned}$$

$$\begin{aligned}&= 0.43 \text{ lbs/day} / 0.65 \\ &= \mathbf{0.68 \text{ lbs/day}}\end{aligned}$$

22. A plant uses 23 gallons of solution from its saturator in treating 220,000 gallons of water. What is the calculated dosage? **c. 1.88 mg/L**

$$\begin{aligned}\text{Dosage (mg/L)} &= \frac{\text{Solution fed (gal)} \times 18,000 \text{ mg/L}}{\text{Capacity (gpd)}} \\ &= \frac{23 \text{ gal} \times 18,000 \text{ mg/L}}{220,000 \text{ gal}} \\ &= \frac{414,000 \text{ mg/L}}{220,000 \text{ gal}} \\ &= \mathbf{1.88 \text{ mg/L}}\end{aligned}$$

23. A water plant produces 0.50 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? **c. 28 gpd**

$$\begin{aligned}\text{Fluoride Feed rate (gpd)} &= \frac{\text{Dose (mg/L)} \times \text{Capacity (gpd)}}{18,000 \text{ mg/L}} \\ &= \frac{1.0 \text{ mg/L} \times 500,000 \text{ gpd}}{18,000 \text{ mg/L}} \\ &= \frac{500,000 \text{ gpd}}{18,000} \\ &= \mathbf{27.78 \text{ gpd}}\end{aligned}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM

1. What is the pressure in psi at the bottom of a tank if the water level is at 34 feet?

b. 14.7 psi

Given:
h = 34 ft.

Need:
Pressure (psi)

Find Answer:

$$\text{Pressure} = (34 \text{ ft.}) \times \frac{(1 \text{ psi})}{(2.31 \text{ ft.})}$$

$$\text{Pressure} = 14.7 \text{ psi}$$

2. Calculate the filtration rate in gpm/ft² for a filter with a surface length of 75 ft and a width of 17 ft when the applied flow is 2 MGD. **d. 1.08 gpm/ft²**

Given:
ℓ = 75 ft.
w = 17 ft.
Q = 2 MGD

Need:
Filtration Rate (gpm/ft²)

Find Answer:

$$\text{Step 1: } Q (\text{gpm}) = \frac{2 \text{ MG}}{1 \text{ day}} \times \frac{1,000,000 \text{ gal}}{1 \text{ MG}} \times \frac{1 \text{ day}}{1440 \text{ min}}$$

$$Q (\text{gpm}) = 1388.89 \text{ gpm}$$

$$\text{Step 2: } A (\text{ft}^2) = \ell (\text{ft}) \times w (\text{ft})$$

$$A (\text{ft}^2) = 75 \text{ ft} \times 17 \text{ ft}$$

$$A (\text{ft}^2) = 1275 \text{ ft}^2$$

$$\text{Step 3: Filtration Rate (gpm/ft}^2) = \frac{Q (\text{gpm})}{A (\text{ft}^2)}$$

$$\text{Filtration Rate (gpm/ft}^2) = \frac{1388.89 \text{ gpm}}{1275 \text{ ft}^2}$$

$$\text{Filtration Rate (gpm/ft}^2) = 1.08 \text{ gpm/ft}^2$$

3. Convert 22 deg Fahrenheit to Celsius. **a. -5.6 °C**

Given:
Temp = 22 °F

Need:
Temp (°C)

Find Answer:

$$\text{Temp (}^\circ\text{C)} = 0.56 (^\circ\text{F} - 32)$$

$$\text{Temp (}^\circ\text{C)} = 0.56 (22 - 32)$$

$$\text{Temp (}^\circ\text{C)} = -5.6 \text{ }^\circ\text{C}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

4. What should the chlorinator setting be (lbs/day) to treat a flow of 2 MGD if the chlorine demand is 5 mg/l and a chlorine residual of 0.8 mg/l is desired?
c. 96.74 lbs/day

Given:

Q = 2 MGD

Demand = 5 mg/l

Residual = 0.8 mg/l

Need:

Feed (lbs/day)

Find Answer:

Step 1: Dose = Demand + Residual

Dose = 5 mg/l + 0.8 mg/l

Dose = 5.8 mg/l

Step 2: Feed (lbs/day) = Dose (mg/l) Q (MGD) (8.34 lbs/gal.)

Feed = (5.8 mg/l) (2 MGD) (8.34 lbs/gal)

Feed = 96.74 lbs/day

5. Calculate the filtration rate in gpm/ft² for a filter with dimensions of 60 ft X 25 ft when the applied flow is 1.3 MGD. **d. 0.60 gpm/ft²**

Given:

ℓ = 60 ft.

w = 25 ft.

Q = 1.3 MGD

Need:

Filtration Rate (gpm/ft²)

Find Answer:

Step 1: $Q \text{ (gpm)} = \frac{1.3 \text{ MG}}{1 \text{ day}} \times \frac{1,000,000 \text{ gal}}{1 \text{ MG}} \times \frac{1 \text{ day}}{1440 \text{ min}}$

Q (gpm) = 902.78 gpm

Step 2: $A \text{ (ft}^2\text{)} = \ell \text{ (ft)} \times w \text{ (ft)}$

A (ft²) = 60 ft x 25 ft

A (ft²) = 1500 ft²

Step 3: $\text{Filtration Rate (gpm/ft}^2\text{)} = \frac{Q \text{ (gpm)}}{A \text{ (ft}^2\text{)}}$

$\text{Filtration Rate (gpm/ft}^2\text{)} = \frac{902.78 \text{ gpm}}{1500 \text{ ft}^2}$

Filtration Rate (gpm/ft²) = 0.60 gpm/ft²

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

6. Convert 50 deg Celsius to Fahrenheit. **c. 122 °F**

Given:
Temp = 50 °C

Need:
Temp (°F)

Find Answer:

$$\text{Temp (°F)} = (1.8 \times \text{°C}) + 32$$

$$\text{Temp (°F)} = (1.8 \times 50) + 32$$

$$\text{Temp (°F)} = 122 \text{ °F}$$

7. A flow of 2 MGD is treated with sodium fluorosilicate. The raw water contains 0.6 mg/l of fluoride and the desired fluoride concentration is 1.2 mg/l. What should the chemical feed rate in lbs/day be? **a. 16.8 lbs/day**

Given:
Q = 2 MGD
Residual = 0.6 mg/l
Demand = 1.2 mg/l
% Chemical Purity = 98% = 0.98

Need:
Fluoride Feed Rate (lbs/day)

Find Answer:

$$\begin{aligned}\text{Step 1: Dose} &= 1.2 \text{ mg/l} - 0.6 \text{ mg/l} \\ \text{Dose} &= 0.6 \text{ mg/l}\end{aligned}$$

$$\text{Step 2: Feed (lbs/day)} = \frac{\text{Dose (mg/l)} \times \text{Q (MGD)} \times (8.34 \text{ lbs/gal})}{(\text{AFI}) (\% \text{ Chem Purity})}$$

$$\text{Feed (lbs/day)} = \frac{(0.6 \text{ mg/l}) (2 \text{ MGD}) (8.34 \text{ lbs/gal})}{(0.607) (0.98)}$$

$$\text{Feed (lbs/day)} = \frac{10.008 \text{ lbs/day}}{0.595}$$

$$\text{Feed (lbs/day)} = 16.8 \text{ lbs/day}$$

8. A head of 20 ft equals a pressure of _____psi. **c. 8.66 psi**

Given:
h = 20 ft

Need:
Pressure (psi)

Find Answer:

$$\text{Pressure (psi)} = 20 \text{ ft} \times \frac{1 \text{ psi}}{2.31 \text{ ft}}$$

$$\text{Pressure (psi)} = 8.66 \text{ psi}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

9. How many pounds per day of HTH (65% available chlorine) are required to disinfect 10,000 feet of 8-inch water line if an initial dose of 20 mg/l is required?

a. 6.77 lbs/day

Given:

$h = 10,000 \text{ ft.}$

$d = 8 \text{ in.}$

$\text{Dose} = 20 \text{ mg/l}$

$\% \text{ Purity} = 65\% = 0.65$

Need:

Feed of HTH (lbs./day)

Find Answer:

$$\text{Step 1: } d = (8 \text{ in.}) \frac{(1 \text{ ft.})}{(12 \text{ in.})}$$

$$d = 8/12 \text{ ft. or } 0.67 \text{ ft.}$$

$$\begin{aligned} \text{Step 2: } V &= 0.785d^2h \\ V &= (0.785) (8/12 \text{ ft.})^2 (10,000 \text{ ft.}) \\ V &= 3488.89 \text{ ft.}^3 \end{aligned}$$

$$\text{Step 3: } V = (3488.89 \text{ ft.}^3) \frac{(7.48 \text{ gal.})}{(1 \text{ ft.}^3)} \frac{(1 \text{ MG})}{(1,000,000 \text{ gal.})}$$

$$V = 0.0261 \text{ MGD}$$

$$\text{Step 4: Feed} = \frac{\text{Dose (mg/l)} Q \text{ (MGD)} (8.34 \text{ lbs/gal})}{\% \text{ Purity (decimal)}}$$

$$\text{Feed} = \frac{(20 \text{ mg/l}) (0.0261 \text{ MGD}) (8.34 \text{ lbs/gal})}{0.65}$$

$$\text{Feed} = \frac{4.35 \text{ lbs/day}}{0.65}$$

$$\text{Feed} = 6.77 \text{ lbs/day}$$

10. The pressure at the bottom of a tank is 28 pounds per square inch. How many feet of water would be in the tank? **d. 64.7 ft**

Given:

$\text{Pressure} = 100 \text{ psi.}$

Need:

$h \text{ (ft)}$

Find Answer:

$$h = (28 \text{ psi}) \times \frac{(2.31 \text{ ft})}{(1 \text{ psi.})}$$

$$h = 64.7 \text{ ft}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

11. How much water is in a full system, if you have a clear well that has a diameter of 20 ft and is 50 ft. tall, and 56,000 ft of 6-inch water lines? **b. 199,641 gal**

Given:

$$d_1 = 20 \text{ ft}$$

$$h_1 = 50 \text{ ft}$$

$$d_2 = 6 \text{ in} = 0.5 \text{ ft}$$

$$h_2 = 56,000 \text{ ft}$$

Need:

Volume of system (gal)

Find Answer:

$$\text{Step 1: } V_1 = 0.785d^2h$$

$$V_1 = (0.785) (20 \text{ ft})^2 (50 \text{ ft})$$

$$V_1 = (0.785) (400 \text{ ft}^2) (50 \text{ ft})$$

$$V_1 = 15,700 \text{ ft}^3$$

$$\text{Step 2: } V_2 = 0.785d^2h$$

$$V_2 = (0.785) (0.5 \text{ ft})^2 (56,000 \text{ ft})$$

$$V_2 = (0.785) (0.25 \text{ ft}^2) (56,000 \text{ ft})$$

$$V_2 = 10,990 \text{ ft}^3$$

$$\text{Step 3: } V_{(\text{system})} = V_1 + V_2$$

$$V_{(\text{system})} = 15,700 \text{ ft}^3 + 10,990 \text{ ft}^3$$

$$V_{(\text{system})} = 26,690 \text{ ft}^3$$

$$\text{Step 4: } V_{(\text{system})} = (26,690 \text{ ft}^3) \times \frac{(7.48 \text{ gal})}{(1 \text{ ft}^3)}$$

$$V_{(\text{system})} = \mathbf{199,641 \text{ gal}}$$

12. There is a water tank at an elevation of 980 ft. and a house at an elevation of 550 ft. What is the pressure (psi) in the line feeding the house? **a. 186 psi**

Given:

$$h_{(\text{tank})} = 980 \text{ ft.}$$

$$h_{(\text{house})} = 550 \text{ ft.}$$

Need:

Pressure (psi)

Find Answer:

$$\text{Step 1: } h = h_{(\text{tank})} - h_{(\text{house})}$$

$$h = 980 \text{ ft} - 550 \text{ ft}$$

$$h = 430 \text{ ft}$$

$$\text{Step 2: Pressure} = (430 \text{ ft.}) \times \frac{(1 \text{ psi})}{(2.31 \text{ ft.})}$$

$$\mathbf{\text{Pressure} = 186 \text{ psi}}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

13. Calculate the filtration rate in gpm/ft² for circular filter with a diameter of 20 ft and the applied flow is 1 MGD. **c. 2.21 gpm/ft²**

Given:

$$d = 20 \text{ ft.}$$

$$Q = 1 \text{ MGD}$$

Need:

$$\text{Filtration Rate (gpm/ft}^2\text{)}$$

Find Answer:

$$\text{Step 1: } Q \text{ (gpm)} = \frac{1 \text{ MG}}{1 \text{ day}} \times \frac{1,000,000 \text{ gal}}{1 \text{ MG}} \times \frac{1 \text{ day}}{1440 \text{ min}}$$

$$Q \text{ (gpm)} = 694.44 \text{ gpm}$$

$$\text{Step 2: } A \text{ (ft}^2\text{)} = 0.785d^2$$

$$A \text{ (ft}^2\text{)} = 0.785 (20 \text{ ft})^2$$

$$A \text{ (ft}^2\text{)} = 314 \text{ ft}^2$$

$$\text{Step 3: Filtration Rate (gpm/ft}^2\text{)} = \frac{Q \text{ (gpm)}}{A \text{ (ft}^2\text{)}}$$

$$\text{Filtration Rate (gpm/ft}^2\text{)} = \frac{694.44 \text{ gpm}}{314 \text{ ft}^2}$$

$$\text{Filtration Rate (gpm/ft}^2\text{)} = 2.21 \text{ gpm/ft}^2$$

14. What is the pumping rate in gpm, if you have a filter that is 50 ft long by 30 ft wide, and the filtration rate is 50 gpm per square foot? **b. 75,000 gpm**

Given:

$$l = 50 \text{ ft.}$$

$$w = 30 \text{ ft.}$$

$$\text{Filtration Rate} = 50 \text{ gpm/ft}^2$$

Need:

$$Q \text{ (gpm)}$$

Find Answer:

$$\text{Step 1: } A \text{ (ft}^2\text{)} = 50 \text{ ft} \times 30 \text{ ft}$$

$$A \text{ (ft}^2\text{)} = 1500 \text{ ft}^2$$

$$\text{Step 2: Filtration Rate (gpm/ft}^2\text{)} = \frac{Q \text{ (gpm)}}{A \text{ (ft}^2\text{)}}$$

$$Q \text{ (gpm)} = \text{Filtration Rate} \left(\frac{\text{gpm}}{\text{ft}^2} \right) \times A \text{ (ft}^2\text{)}$$

$$Q \text{ (gpm)} = \frac{50 \text{ gpm}}{\text{ft}^2} \times 1500 \text{ ft}^2$$

$$Q \text{ (gpm)} = 75,000 \text{ gpm}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

15. Convert a filter rate from 30 gpm/sq ft to inches per hour. **d. 2887 in/hr**

Given:

$$\text{Filtration Rate} = 30 \text{ gpm/ft}^2$$

Need:

$$\text{Filtration Rate (in/hr)}$$

Find Answer:

$$\text{Step 1: Filtration Rate (gpm/ft}^2\text{)} = \frac{Q \text{ (gpm)}}{A \text{ (ft}^2\text{)}}$$

$$\text{Filtration Rate (gpm/ft}^2\text{)} = \frac{(30 \text{ gpm})}{(1 \text{ ft}^2)}$$

$$\text{Filtration Rate (gpm/ft}^2\text{)} = \frac{(30 \text{ gal})}{(1 \text{ min})} \div (1 \text{ ft}^2)$$

Step 2: Convert 30 gal/min to ft³/min.

$$Q = \frac{(30 \text{ gal})}{(1 \text{ min})} \times \frac{(1 \text{ ft}^3)}{(7.48 \text{ gal})}$$

$$Q = \frac{(30 \text{ ft}^3)}{(7.48 \text{ min})}$$

$$Q = 4.01 \text{ ft}^3/\text{min}$$

Step 3: Substitute Q back into equation to find filtration rate in ft/min

$$\text{Filtration Rate (ft/min)} = \frac{Q \text{ (ft}^3/\text{min)}}{A \text{ (ft}^2\text{)}}$$

$$\text{Filtration Rate (ft/min)} = \frac{4.01 \text{ (ft}^3/\text{min)}}{1 \text{ (ft}^2\text{)}}$$

$$\text{Filtration Rate (ft/min)} = 4.01 \text{ ft/min}$$

Step 4: Convert ft/min into in/hr.

$$\text{Filtration Rate (in/min)} = \frac{(4.01 \text{ ft})}{(1 \text{ min})} \times \frac{(12 \text{ in})}{(1 \text{ ft})} \times \frac{(60 \text{ min})}{(1 \text{ hr})}$$

$$\text{Filtration Rate (in/min)} = (4.01) (12) (60) \text{ in/hr}$$

$$\text{Filtration Rate (gpm/ft}^2\text{)} = 2887.2 \text{ in/hr}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

16. Calculate the dosage if your chlorinator is set to feed chlorine at 95 lbs into 4 MG?

a. 2.85 mg/L

Given:

Feed = 95 lbs

Q = 4 MG

Need:

Dose (mg/l)

Find Answer:

$$\text{Dose} = \frac{\text{Feed (lbs/day)}}{\text{Q (MGD)} (8.34 \text{ lbs/gal})} \quad \text{Note: day cancels out}$$

$$\text{Dose} = \frac{95 \text{ lbs}}{(4 \text{ MG}) (8.34 \text{ lbs/gal})}$$

$$\text{Dose} = 2.85 \text{ mg/l}$$

17. A flow of 1.5 MGD is _____ gpm? **c. 1042 gpm**

Given:

Q = 1.5 MGD

Need:

Q (gpm)

Find Answer:

$$Q = \frac{(1.5 \text{ MG}) (1 \text{ day}) (1,000,000 \text{ gal})}{(1 \text{ day}) (1440 \text{ min.}) (1 \text{ MG})}$$

$$Q = 1041.67 \text{ gpm}$$

18. Convert 10 mg/L to grains per gallon. **b. 0.58 gpg**

Given:

Dose = 10 mg/L

Need:

Dose (gpg)

Find Answer:

$$\text{Dose} = 10 \text{ mg/L} \times \frac{1 \text{ gpg}}{17.12 \text{ mg/L}}$$

$$\text{Dose} = 0.58 \text{ gpg}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

19. A stream has a flow of 14 cfs. What is the mgd flow of the stream? **a. 9.05 MGD**

Given:

$$Q = 14 \text{ ft.}^3/\text{sec.}$$

Need:

$$Q \text{ (MGD)}$$

Find Answer:

$$Q = \frac{(14 \text{ ft.}^3) (7.48 \text{ gal.}) (1 \text{ MG}) (86,400 \text{ sec.})}{(1 \text{ sec.}) (1 \text{ ft.}^3) (1,000,000 \text{ gal.}) (1 \text{ day})}$$

$$Q = 9.05 \text{ MGD}$$

20. What is the detention time (days) for a tank 50 ft. high & 40 ft. diameter & flow is 0.5 MGD? **d. 0.94 days**

Given:

$$d = 40 \text{ ft.}$$

$$h = 50 \text{ ft.}$$

$$Q = 0.5 \text{ MGD}$$

Need:

$$\text{time (days)}$$

Find Answer:

$$\text{Step 1: } V = 0.785d^2h$$

$$V = (0.785) (40 \text{ ft.})^2 (50 \text{ ft.})$$

$$V = 62,800 \text{ ft.}^3$$

$$\text{Step 2: } V = \frac{(62,800 \text{ ft.}^3) \times (7.48 \text{ gal.}) \times (1 \text{ MG})}{(1 \text{ ft.}^3) (1,000,000 \text{ gal.})}$$

$$V = 0.47 \text{ MG}$$

$$\text{Step 3: } t = \frac{V}{Q}$$

$$t = \frac{(0.47 \text{ MG})}{(0.5 \text{ MGD})}$$

$$t = 0.94 \text{ days}$$

APPENDIX B - ANSWERS TO CLASS II - MATH PRACTICE EXAM (CONTINUED)

21. A tank is 25 ft long, 13 ft wide, and 20 ft high. The water level is at 12 ft. What is the volume? **c. 29,172 gal**

Given:

$$\ell = 25 \text{ ft.}$$

$$w = 13 \text{ ft}$$

$$h = 20 \text{ ft}$$

$$h_1 = 12 \text{ ft}$$

Find Answer:

$$\text{Step 1: } V = \ell w h_1$$

$$V = (25 \text{ ft}) (13 \text{ ft}) (12 \text{ ft})$$

$$V = 3900 \text{ ft}^3$$

Need:

$$V (\text{gal})$$

$$\text{Step 2: } V = (3900 \text{ ft}^3) \times \frac{(7.48 \text{ gal})}{(1 \text{ ft}^3)}$$

$$\mathbf{V = 29,172 \text{ gal.}}$$

22. How many pounds of 65% HTH chlorine will be required to disinfect 400 feet of 8-inch water main at 50 ppm? **a. 0.67 lbs**

Given:

$$\% \text{ Purity} = 0.65$$

$$d = 8 \text{ in} = 8/12 \text{ ft}$$

$$h = 400 \text{ ft}$$

$$\text{Dose} = 50 \text{ ppm} = 50 \text{ mg/L}$$

Find Answer:

$$\text{Step 1: } V = 0.785 d^2 h$$

$$V = (0.785) (0.67 \text{ ft.})^2 (400 \text{ ft.})$$

$$V = 140.95 \text{ ft.}^3$$

Need:

$$\text{Feed (lbs)}$$

$$\text{Step 2: } V = \frac{(140.95 \text{ ft.}^3) \times (7.48 \text{ gal.}) \times (1 \text{ MG})}{(1 \text{ ft.}^3) (1,000,000 \text{ gal})}$$

$$V = 0.00105 \text{ MG}$$

$$\text{Step 3: Feed (lbs/day)} = \frac{\text{Dose (mg/L)} Q (\text{MGD}) (8.34 \text{ lb/gal})}{\% \text{ Purity}}$$

$$\text{Feed (lbs/day)} = \frac{(50 \text{ mg/L}) (0.00105 \text{ MGD}) (8.34 \text{ lb/gal})}{0.65}$$

$$\text{Feed (lbs/day)} = \frac{0.43785 \text{ lbs}}{0.65}$$

$$\text{Feed (lbs/day)} = 0.67 \text{ lbs/day}$$

$$\mathbf{HTH \text{ Feed (lbs)} = 0.67 \text{ lbs.}}$$

APPENDIX C - ANSWERS TO CLASS III – PRACTICE #1

1. A water system bills at a rate of \$0.40/1,000 gallons for the first 10,000 gallons; \$0.30/1,000 for the next 15,000 gallons; and \$0.15/1,000 gallons for all over 25,000 gallons. If a customer uses 35,000 gallons, how much is the water bill?

$$\begin{array}{l} 35,000 \text{ gallons} \\ -10,000 \text{ gallons } (\$0.40/1,000 \text{ gal}) = \$4.00 \\ 25,000 \text{ gallons} \\ -15,000 \text{ gallons } (\$0.30/1,000 \text{ gal}) = \$4.50 \\ 10,000 \text{ gallons } (\$0.15/1,000 \text{ gal}) = \$1.50 \\ \hline \mathbf{\$10.00} \end{array}$$

2. The total master meter reading for a system for one month was 44,413,296 gallons. The domestic meters total 19,396,413 gallons, the industrial meters total 8,256,497 gallons, and the purchased meters show a total of 6,989,235 gallons pumped. What percentage of total water was lost or unaccounted for?

$$19,396,413 \text{ gallons} + 8,256,497 \text{ gallons} + 6,989,235 \text{ gallons} = 34,642,145 \text{ gallons used}$$

$$\frac{\text{Water produced} - \text{water used}}{\text{Water produced}} \times 100 = \frac{44,413,296 - 34,642,145}{44,413,296} \times 100 =$$

$$\frac{9,771,151}{44,413,296} \times 100 = 0.22 \times 100 = \mathbf{22\%}$$

3. A filter is 45 feet long and 20 feet wide. During a test of flow rate, the influent valve to the filter is closed for seven minutes. The water level drops 20 inches during this period. What is the filtration rate for the filter in gpm?

$$\frac{20 \text{ in (1 ft)}}{(12 \text{ in})} = 1.67 \text{ ft}$$

$$\begin{aligned} \text{Volume} &= \text{length} \times \text{width} \times \text{height} \times 7.48 \text{ gal/ft}^3 = 45 \text{ ft} \times 20 \text{ ft} \times 1.67 \text{ ft} \times 7.48 \text{ gal/ft}^3 = \\ &= \frac{11,242.44 \text{ gal}}{7 \text{ min}} = \mathbf{1,606.06 \text{ gpm}} \end{aligned}$$

4. A 5-log removal of contaminants is expressed in terms of

$$5 \log = \mathbf{99.999}$$

APPENDIX C - ANSWERS TO CLASS III – PRACTICE #1 (CONTINUED)

5. How many pounds of HTH (70% available chlorine) would be necessary to disinfect 5,000 feet of 18-inch water main with 50 mg/L chlorine?

$$\frac{18 \text{ in (1 ft)}}{(12 \text{ in})} = 1.5 \text{ ft}$$

$$\begin{aligned} \text{Volume} &= 0.785 \times D^2 \times H \times 7.48 \text{ gal/ft}^3 = 0.785 \times 1.5 \text{ ft} \times 1.5 \text{ ft} \times 5000 \text{ ft} \times 7.48 \text{ gal/ft}^3 = \\ &= \frac{66,057.75 \text{ gal (1MG)}}{(1,000,000 \text{ gal})} = 0.066 \text{ MG} \end{aligned}$$

$$\begin{aligned} \text{lbs} &= \text{dose} \times \text{flow} \times 8.34 \text{ lbs/gal} = 50 \text{ mg/L} \times 0.066 \text{ MG} \times 8.34 \text{ lbs/gal} = 27.5 \text{ lbs/day} \\ &= (27.5 \text{ lbs/day})/0.70 = \mathbf{39.29 \text{ lbs/day}} \end{aligned}$$

6. A clear well at a water plant is 30 feet wide by 25 feet long by 15 feet deep. What is the actual CT value of this tank if the free chlorine is 2.0 mg/L and the peak pumpage into the clear well is 0.75 MGD. Assume a T₁₀ valve of 10% based on a dye tracer study.

$$\begin{aligned} \text{Volume} &= \text{length} \times \text{width} \times \text{height} \times 7.48 \text{ gal/ft}^3 = 30 \text{ ft} \times 25 \text{ ft} \times 15 \text{ ft} \times 7.48 \text{ gal/ft}^3 = \\ &= 84,150 \text{ gal} \end{aligned}$$

$$\text{Flow} = \frac{0.75 \text{ MGD (694.4 gpm)}}{(1 \text{ MGD})} = 520.8 \text{ gpm}$$

$$\text{CT, mg/L-min} = \frac{(\text{Vol, gal})(T_{10})(\text{Free Chlorine Residual, mg/L})}{\text{Flow, gpm}}$$

$$= \frac{(84,150 \text{ gal})(0.1)(2.0 \text{ mg/L})}{520.8 \text{ gpm}} = \frac{16830 \text{ mg/L}}{520.8 \text{ gpm}} = \mathbf{32.3 \text{ mg/L-min}}$$

7. What is the minimum free chlorine residual required for the clear well to provide adequate disinfection if the required CT value is 18 mg/L-min and the T₁₀ minimum detention time based on tracer studies is 30 minutes.

$$\text{Free Chlorine Residual, mg/L} = \frac{(\text{CT, mg/L-min})}{T_{10, \text{ min}}} = \frac{(18 \text{ mg/L-min})}{30 \text{ min}} = \mathbf{0.6 \text{ mg/L}}$$

8. How many pounds of copper sulfate will be needed to dose a reservoir with 0.7 mg/L copper? The reservoir volume is 15 million gallons. The copper sulfate is 25%?

$$\text{Feed (lbs/day)} = \text{dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lbs/gal}) \div \% \text{ purity (decimal)}$$

$$= \frac{0.7 \text{ mg/L} \times 15 \text{ MGD} \times 8.34 \text{ lbs/gal}}{0.25} = \frac{87.57}{0.25} = \mathbf{350.28 \text{ lbs}}$$

APPENDIX C - ANSWERS TO CLASS III – PRACTICE #1 (CONTINUED)

9. A 8-inch drop in 100 feet would be equal to :

$$\frac{8 \text{ in (1 ft)}}{(12 \text{ in})} = \frac{0.67 \text{ ft}}{100 \text{ ft}} \times 100\% = \mathbf{0.67\%}$$

10. A filter is 12 feet wide x 12 feet long x 8 feet deep. For a backwash rate of 10 gpm/ft², what backwash flow rate is needed?

$$\text{Backwash flow, gpm} = (\text{Backwash rate, gpm/ft}^2) (\text{Surface area, ft}^2)$$

$$= 10 \text{ gpm/ft}^2 \times (12 \text{ ft} \times 12 \text{ ft}) = \mathbf{1440 \text{ gpm}}$$

11. What is the filtration rate for a filter bed 20 feet x 100 feet if the water level drops 16 inches in one minute?

$$\frac{16 \text{ in (1 ft)}}{(12 \text{ in})} = 1.33 \text{ ft}$$

$$\text{Volume} = \text{length} \times \text{width} \times \text{height} \times 7.48 \text{ gal/ft}^3 = 20 \text{ ft} \times 100 \text{ ft} \times 1.33 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 19,896.8 \text{ gal/min}$$

$$\text{Filtration rate, gpm/ft}^2 = \frac{\text{Flow, gpm}}{\text{Surface area, ft}^2} = \frac{19,896.9 \text{ gpm}}{(20 \text{ ft} \times 100 \text{ ft})} = \mathbf{9.95 \text{ gpm/ft}^2}$$

12. The optimum level for fluoride in drinking water at your 0.45 MGD plant is 1.0 mg/L. Only trace amounts of fluoride naturally occur in your raw water. The daily analyzation result measures 1.02 mg/L. How many gallons of saturated (4 gram per 100 mL of water) NaF solution was pumped into the clearwell. A saturated solution contains an AFI of 0.452 and is 98% pure.

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

$$= \frac{(1.02 \text{ mg/L}) (450,000 \text{ gal})}{18,000 \text{ mg/L}} = \frac{459,000 \text{ gal}}{18,000} = \mathbf{25.5 \text{ gal}}$$

13. The optimum level alum dose from jar tests is 10 mg/L. Determine the setting on the liquid alum feeder in gallons per day when the flow is 0.65 MGD. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon solution.

$$\text{Feed (lbs/day)} = \text{dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lbs/gal})$$

$$= (10 \text{ mg/L}) (0.65 \text{ MGD}) (8.34 \text{ lbs/day}) = \frac{54.21 \text{ lbs/day (1 gal)}}{(5.36 \text{ lbs})} = \mathbf{10.1 \text{ gal}}$$

APPENDIX C - ANSWERS TO CLASS III – PRACTICE #1 (CONTINUED)

14. A bucket placed under a dry chemical feeder weighed 0.6 pounds empty and 2.5 pounds after 30 minutes. The actual chemical feed rate in pounds per day is:

$$\frac{2.5 \text{ lbs} - 0.6 \text{ lbs}}{30 \text{ min}} = \frac{1.9 \text{ lbs (1440 min)}}{30 \text{ min (1 day)}} = \frac{2736 \text{ lbs}}{30 \text{ day}} = \mathbf{91.2 \text{ lbs/day}}$$

15. The liquid alum feed pump is set at 100% stroke and at a 100% speed the pump will feed 75 gpd of solution. What speed should the pump setting be if the plant produces 2.5 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 pounds of alum per gallon of liquid solution.

$$\text{Feed (lbs/day)} = \text{dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lbs/gal})$$

$$= (10 \text{ mg/L}) (2.5 \text{ MGD}) (8.34 \text{ lbs/day}) = \frac{208.5 \text{ lbs (1 gal)}}{\text{day (5.36 lbs)}} = \mathbf{38.9 \text{ gal/day}}$$

$$\frac{100\%}{75 \text{ gpd}} = \frac{X}{38.9}$$

$$75g (X) = (38.9)(100\%)$$

$$X = \frac{(38.9 \text{ gpd})(100\%)}{75 \text{ gpd}} = \frac{3890 \%}{75} = \mathbf{51.87\%}$$

16. A customer reports a water leak near the bottom of the hill between your tank and the booster. Your SCADA records that the tank level and when your booster pumps kick on and off. Your tank is 50.5 feet in diameter and the base elevation is 800.5 feet and the overflow elevation is 877.9 feet. Your chart indicates the tank started losing water at 11:00 AM and you isolated the leak at 1:30 PM. The water level in the tank at 11:00 AM was 22.5 feet and at 1:30 PM the level was 19.2 feet. During the leak one pump was running in the booster station at a rate of 233 gpm. For this period you have determined your customers would normally use 12,000 gph.

$$\text{Height} = 22.5 \text{ ft} - 19.2 \text{ ft} = 3.3 \text{ ft}$$

$$\text{Tank Volume} = 0.785 \times D^2 \times H \times 7.48 \text{ gal/ft}^3 = 0.785 \times 50.5 \text{ ft} \times 50.5 \text{ ft} \times 3.3 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 49,416 \text{ gal (in 2.5 hours)}$$

$$\text{Pump Volume} = \frac{233 \text{ gal (60 min)}}{\text{min (1 hr)}} (2.5 \text{ hr}) = 34,950 \text{ gal}$$

$$\text{Customer Volume} = \frac{12,000 \text{ gal (2.5 hr)}}{\text{hr}} = 30,000 \text{ gal}$$

$$\begin{aligned} \text{Water lost} &= \text{Water pumped} - \text{Water used} = \\ &= 49,416 \text{ gal} + 34,950 \text{ gal} - 30,000 \text{ gal} = \mathbf{54,366 \text{ gal}} \end{aligned}$$

APPENDIX C - ANSWERS TO CLASS III – PRACTICE #1 (CONTINUED)

17. You have a filter that measures 8 feet wide by 15 feet long. The media in the filter is standard filter sand with an anthracite cap. Your backwash pump has a maximum flow rate of 2,000 gpm. The freeboard above the media is 4 feet and the waste outlet on the filter is 10 inches in diameter. Your filter achieves 50% expansion at a backwash rate of 2,200 gpm. What is your optimum backwash rate in gpm/ft²?

$$\text{Backwash Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{2,200 \text{ gpm}}{(8 \text{ ft} \times 12 \text{ ft})} = \mathbf{22.92 \text{ gpm/ft}^2}$$

APPENDIX D - ANSWERS TO CLASS III – PRACTICE #2

1. A water system bills at a rate of \$0.35/1,000 gallons for the first 10,000 gallons; \$0.25/1,000 for the next 15,000 gallons; and \$0.20/1,000 gallons for all over 25,000 gallons. If a customer uses 35,000 gallons, how much is the water bill?

$$\begin{array}{r} 35,000 \text{ gallons} \\ -10,000 \text{ gallons } (\$0.35/1,000 \text{ gal}) = \$3.50 \\ \hline 25,000 \text{ gallons} \\ -15,000 \text{ gallons } (\$0.25/1,000 \text{ gal}) = \$3.75 \\ \hline 10,000 \text{ gallons } (\$0.20/1,000 \text{ gal}) = \$2.00 \\ \hline \mathbf{\$9.25} \end{array}$$

2. The total master meter reading for a system for one month was 24,400,296 gallons. The domestic meters total 9,413,211 gallons, the industrial meters total 277,497 gallons, and the purchased meters show a total of 89,235 gallons pumped. What percentage of total water was lost or unaccounted for?

$$9,413,211 \text{ gallons} + 277,497 \text{ gallons} + 89,235 \text{ gallons} = 9,779,943 \text{ gallons used}$$

$$\frac{\text{Water produced} - \text{water used}}{\text{Water produced}} \times 100 = \frac{24,400,296 - 9,779,943}{24,400,296} \times 100 =$$

$$\frac{14,620,353}{24,400,296} \times 100 = 0.599 \times 100 = \mathbf{59.9\%}$$

3. A filter is 33 feet long and 25 feet wide. During a test of flow rate, the influent valve to the filter is closed for seven minutes. The water level drops 18 inches during this period. What is the filtration rate for the filter in gpm?

$$\frac{18 \text{ in (1 ft)}}{(12 \text{ in})} = 1.5 \text{ ft}$$

$$\begin{aligned} \text{Volume} &= \text{length} \times \text{width} \times \text{height} \times 7.48 \text{ gal/ft}^3 \\ &= 33 \text{ ft} \times 25 \text{ ft} \times 1.5 \text{ ft} \times 7.48 \text{ gal/ft}^3 = 9,256.5 \text{ gal} \\ &= \frac{9,256.5 \text{ gal}}{7 \text{ min}} = \mathbf{1,322.36 \text{ gpm}} \end{aligned}$$

4. A 4-log removal of contaminants is expressed in terms of

$$4 \log = 99.99$$

APPENDIX D - ANSWERS TO CLASS III – PRACTICE #2 (CONTINUED)

5. How many pounds of HTH (70% available chlorine) would be necessary to disinfect 10,000 feet of 12-inch water main with 50 mg/L chlorine?

$$\frac{12 \text{ in (1 ft)}}{(12 \text{ in})} = 1 \text{ ft}$$

$$\begin{aligned}\text{Volume} &= 0.785 \times D^2 \times H \times 7.48 \text{ gal/ft}^3 \\ &= 0.785 \times 1 \text{ ft} \times 1 \text{ ft} \times 10,000 \text{ ft} \times 7.48 \text{ gal/ft}^3 = \\ &= \frac{58,718 \text{ gal (1MG)}}{(1,000,000 \text{ gal})} = 0.059 \text{ MG}\end{aligned}$$

$$\begin{aligned}\text{lbs} &= \text{dose} \times \text{flow} \times 8.34 \text{ lbs/gal} = 50 \text{ mg/L} \times 0.059 \text{ MG} \times 8.34 \text{ lbs/gal} = 24.6 \text{ lbs/day} \\ &= (24.6 \text{ lbs/day})/0.70 = \mathbf{35.15 \text{ lbs/day}}\end{aligned}$$

6. A clear well at a water plant is 20 feet wide by 15 feet long by 25 feet deep. What is the actual CT value of this tank if the free chlorine is 3.5 mg/L and the peak pumpage into the clear well is 0.65 MGD. Assume a T₁₀ value of 10% based on a dye tracer study.

$$\begin{aligned}\text{Volume} &= \text{length} \times \text{width} \times \text{height} \times 7.48 \text{ gal/ft}^3 \\ &= 20 \text{ ft} \times 15 \text{ ft} \times 25 \text{ ft} \times 7.48 \text{ gal/ft}^3 = \\ &= 56,100 \text{ gal}\end{aligned}$$

$$\text{Flow} = \frac{0.65 \text{ MGD (694.4 gpm)}}{(1 \text{ MGD})} = 451.36 \text{ gpm}$$

$$\begin{aligned}\text{CT, mg/L-min} &= \frac{(\text{Vol, gal})(T_{10})(\text{Free Chlorine Residual, mg/L})}{\text{Flow, gpm}} \\ &= \frac{(56,100 \text{ gal})(0.1)(3.5 \text{ mg/L})}{451.36 \text{ gpm}} = \frac{19,635 \text{ mg/L}}{451.36 \text{ min}} = \mathbf{43.5 \text{ mg/L-min}}\end{aligned}$$

7. What is the minimum free chlorine residual required for the clear well to provide adequate disinfection if the required CT value is 28 mg/L-min and the T₁₀ minimum detention time based on tracer studies is 30 minutes.

$$\text{Free Chlorine Residual, mg/L} = \frac{(\text{CT, mg/L-min})}{T_{10}, \text{ min}} = \frac{(28 \text{ mg/L-min})}{30 \text{ min}} = \mathbf{0.93 \text{ mg/L}}$$

APPENDIX D - ANSWERS TO CLASS III – PRACTICE #2 (CONTINUED)

8. How many pounds of copper sulfate will be needed to dose a reservoir with 0.65 mg/L copper? The reservoir volume is 12 million gallons. The copper sulfate is 25%?

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

$$= \frac{0.65 \text{ mg/L} \times 12 \text{ MGD} \times 8.34 \text{ lbs/gal}}{0.25} = \frac{65.05}{0.25} = \mathbf{260.21 \text{ lbs}}$$

9. A 9-inch drop in 100 feet would be equal to :

$$\frac{9 \text{ in (1 ft)}}{(12 \text{ in})} = \frac{0.75 \text{ ft}}{100 \text{ ft}} \times 100\% = \mathbf{0.75\%}$$

10. A filter is 10 feet wide x 12 feet long x 18 feet deep. For a backwash rate of 40 gpm/ft², what backwash flow rate is needed?

Backwash flow, gpm = (Backwash rate, gpm/ft²) (Surface area, ft²)

$$= \frac{40 \text{ gpm}}{\text{ft}^2} \times (10 \text{ ft} \times 12 \text{ ft}) = \mathbf{4800 \text{ gpm}}$$

11. What is the filtration rate for a filter bed 30 feet x 70 feet if the water level drops 18 inches in two minute?

$$\frac{18 \text{ in (1 ft)}}{(12 \text{ in})} = 1.5 \text{ ft}$$

$$\begin{aligned} \text{Volume} &= \text{length} \times \text{width} \times \text{height} \times 7.48 \text{ gal/ft}^3 \\ &= 30 \text{ ft} \times 70 \text{ ft} \times 1.5 \text{ ft} \times 7.48 \text{ gal/ft}^3 = \\ &= 23,562 \text{ gal/ 2 min} \end{aligned}$$

$$\text{Filtration rate, gpm/ft}^2 = \frac{\text{Flow, gpm}}{\text{Surface area, ft}^2} = \frac{11,781 \text{ gpm}}{(30 \text{ ft} \times 70 \text{ ft})} = \mathbf{5.61 \text{ gpm/ft}^2}$$

12. The optimum level for fluoride in drinking water at your 0.65 MGD plant is 1.0 mg/L. Only trace amounts of fluoride naturally occur in your raw water. The daily analyzation result measures 0.98 mg/L. How many gallons of saturated (4 gram per 100 mL of water) NaF solution was pumped into the clearwell. A saturated solution contains an AFI of 0.452 and is 98% pure.

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

$$= \frac{(0.98 \text{ mg/L}) (650,000 \text{ gal})}{18,000 \text{ mg/L}} = \frac{637,000 \text{ gal}}{18,000} = \mathbf{35.4 \text{ gal}}$$

APPENDIX D - ANSWERS TO CLASS III – PRACTICE #2 (CONTINUED)

13. The optimum level alum dose from jar tests is 7 mg/L. Determine the setting on the liquid alum feeder in gallons per day when the flow is 234,500 gpd. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon solution.

$$\text{Feed (lbs/day)} = \text{dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lbs/gal})$$

$$= (7 \text{ mg/L}) (0.2345 \text{ MGD}) (8.34 \text{ lbs/day}) = \frac{13.69 \text{ lbs (1 gal)}}{\text{day (5.36 lbs)}} = \mathbf{2.55 \text{ gal}}$$

14. A bucket placed under a dry chemical feeder weighed 0.9 pounds empty and 5.3 pounds after 15 minutes. The actual chemical feed rate in pounds per day is:

$$\frac{5.3 \text{ lbs} - 0.9 \text{ lbs}}{15 \text{ min}} = \frac{4.4 \text{ lbs (1440 min)}}{15 \text{ min (1 day)}} = \frac{6,336 \text{ lbs}}{15 \text{ day}} = \mathbf{422.4 \text{ lbs/day}}$$

15. The liquid alum feed pump is set at 100% stroke and at a 100% speed the pump will feed 80 gpd of solution. What speed should the pump setting be if the plant produces 1.0 MGD? The liquid alum is being dosed from the jar tests results at 12 mg/L. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon of liquid solution.

$$\text{Feed (lbs/day)} = \text{dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lbs/gal})$$

$$= (12 \text{ mg/L}) (1.0 \text{ MGD}) (8.34 \text{ lbs/day}) = \frac{100.8 \text{ lbs (1 gal)}}{\text{day (5.36 lbs)}} = \mathbf{18.67 \text{ gal}}$$

$$\frac{100\%}{80 \text{ gpd}} = \frac{X}{18.67 \text{ gpd}}$$

$$80 \text{ gpd} (X) = (18.67 \text{ gpd})(100\%)$$

$$X = \frac{(18.67)(100\%)}{80} = \frac{1867\%}{80} = \mathbf{23.3 \%}$$

APPENDIX D - ANSWERS TO CLASS III – PRACTICE #2 (CONTINUED)

16. A customer reports a water leak near the bottom of the hill between your tank and the booster. Your SCADA records that the tank level and when your booster pumps kick on and off. Your tank is 45.5 feet in diameter and the base elevation is 650.5 feet and the overflow elevation is 767.9 feet. Your chart indicates the tank started losing water at 11:00 AM and you isolated the leak at 1:30 PM. The water level in the tank at 11:00 AM was 33.5 feet and at 1:30 PM the level was 29.2 feet. During the leak one pump was running in the booster station at a rate of 255 gpm. For this period you have determined your customers would normally use 11,300 gph.

$$\text{Height} = 33.5 \text{ ft} - 29.2 \text{ ft} = 4.3 \text{ ft}$$

$$\begin{aligned}\text{Tank Volume} &= 0.785 \times D^2 \times H \times 7.48 \text{ gal/ft}^3 \\ &= 0.785 \times 45.5 \text{ ft} \times 45.5 \text{ ft} \times 4.3 \text{ ft} \times 7.48 \text{ gal/ft}^3 = \\ &= 52,271 \text{ gal (in 2.5 hours)}\end{aligned}$$

$$\text{Pump Volume} = \frac{255 \text{ gal (60 min)}}{\text{min (1 hr)}} (2.5 \text{ hr}) = 38,250 \text{ gal}$$

$$\text{Customer Volume} = \frac{11,300 \text{ gal}}{\text{hr}} (2.5 \text{ hr}) = 28,250 \text{ gal}$$

$$\begin{aligned}\text{Water lost} &= \text{Water pumped} - \text{Water used} = \\ &= 52,271 \text{ gal} + 38,250 \text{ gal} - 28,250 \text{ gal} = \mathbf{62,271 \text{ gal}}\end{aligned}$$

17. You have a filter that measures 10 feet wide by 15 feet long. The media in the filter is standard filter sand with an anthracite cap. Your backwash pump has a maximum flow rate of 2,000 gpm. The freeboard above the media is 4 feet and the waste outlet on the filter is 8 inches in diameter. Your filter achieves 50% expansion at a backwash rate of 2,400 gpm. What is your optimum backwash rate in gpm/ft²?

$$\text{Backwash Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{2,400 \text{ gpm}}{(10 \text{ ft} \times 15 \text{ ft})} = \mathbf{16 \text{ gpm/ft}^2}$$

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1

Use the following information to answer the questions Your water treatment plant uses potassium permanganate to oxidize iron and manganese from the raw water. The plant processes are traditional, complete treatment with greensand filters.

- potassium permanganate dose = $\{2 \times (\text{raw Mn, mg/L})\} + \text{raw Fe, mg/L} + \text{desired residual}$
- potassium permanganate in inventory = 15,000 lbs.
- calibration beaker weight = 450 g
- plant flow = 2.9 MGD
- raw water manganese = 2.8 mg/L
- raw water iron = 0.6 mg/L
- chemical supplier does not work on Saturday or Sunday
- a single bulk delivery cannot exceed 48,000 lbs
- desired permanganate residual = 0.1 mg/L
- price for a full bulk delivery = \$3,520.00/ton
- time required from order to delivery = 10 working days
- price for deliveries under 12,000 lbs = \$3,250.00/ton

Dry Feeder Output per 15 minute grab sample

Setting	Sample weight including beaker
30%	775 grams
50%	992 grams
70%	1248 grams

1. What is your potassium permanganate dose in lbs/day?

$$\text{Dose (mg/L)} = 2(\text{raw Mn}) + \text{raw Fe} + \text{desired Residual}$$

$$\text{Dose (mg/L)} = 2(2.8 \text{ mg/L}) + 0.6 \text{ mg/L} + 0.1 \text{ mg/L}$$

$$\text{Dose (mg/L)} = 5.6 \text{ mg/L} + 0.6 \text{ mg/L} + 0.1 \text{ mg/L}$$

$$\text{Dose (mg/L)} = 6.3 \text{ mg/L}$$

$$\text{Feed (lb/day)} = [\text{Dose (mg/L)}] \times [\text{Flow (MGD)}] \times [8.34 \text{ lb/gal}]$$

$$\text{Feed (lb/day)} = (6.3 \text{ mg/L}) \times (2.9 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = \mathbf{152.37 \text{ lb/day}}$$

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1 (CONTINUED)

2. What is the dry feeder calibration results?

30 % yields

$$775 \text{ g} - 420 \text{ g} = 355 \text{ g} \times \frac{1 \text{ lb}}{454 \text{ g}} = \frac{0.78 \text{ lbs} \times 60 \text{ min} \times 24 \text{ hr}}{15 \text{ min} \times 1 \text{ hr} \times 1 \text{ day}} = 75 \text{ lbs/day}$$

50 % yields

$$992 \text{ g} - 420 \text{ g} = 572 \text{ g} \times \frac{1 \text{ lb}}{454 \text{ g}} = \frac{1.26 \text{ lbs} \times 60 \text{ min} \times 24 \text{ hr}}{15 \text{ min} \times 1 \text{ hr} \times 1 \text{ day}} = 121 \text{ lbs/day}$$

70 % yields

$$1248 \text{ g} - 420 \text{ g} = 828 \text{ g} \times \frac{1 \text{ lb}}{454 \text{ g}} = \frac{1.82 \text{ lbs} \times 60 \text{ min} \times 24 \text{ hr}}{15 \text{ min} \times 1 \text{ hr} \times 1 \text{ day}} = 175 \text{ lbs/day}$$

$$\frac{50 \%}{X} = \frac{121 \text{ lbs/day}}{152 \text{ lbs/day}}$$

$$121 \text{ lbs/day} (X) = (152 \text{ lbs/day}) (50\%)$$

$$X = \frac{(152 \text{ lbs/day}) (50\%)}{121 \text{ lbs/day}} = \frac{7,600\%}{121} = 62.8\%$$

$$\frac{70 \%}{X} = \frac{175 \text{ lbs/day}}{152 \text{ lbs/day}}$$

$$175 \text{ lbs/day} (X) = (152 \text{ lbs/day}) (70\%)$$

$$X = \frac{(152 \text{ lbs/day}) (70\%)}{175 \text{ lbs/day}} = \frac{10,640\%}{175} = 60.8\%$$

$$\frac{62.8 \%}{2} + \frac{60.8\%}{2} = \frac{123.6 \%}{2} = \mathbf{61.8\%}$$

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1 (CONTINUED)

3. What is the projected cost (to the nearest hundred) for potassium permanganate for a 12 month period?

$$\frac{(152.37 \text{ lb})}{(1 \text{ day})} (365 \text{ days}) = 55,615.05 \text{ lb}$$

$$55,615 \text{ lb} - 48,000 \text{ lbs/bulk} = 7,615 \text{ lbs/partial load}$$

$$48,000 \text{ lbs} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = 24 \text{ ton} \times \frac{\$3520}{\text{ton}} = \$84,480$$

$$7,615 \text{ lbs} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = 3.81 \text{ ton} \times \frac{\$3250}{\text{ton}} = \$12,374$$

$$\$84,480 + \$12,374 = \mathbf{\$96,854}$$

Therefore, the projected cost (to the nearest hundred) would be **\$96,900**.

4. How many days can you operate before you must place an order for a full bulk load?

$$15,000 \text{ lb} \div 152.37 \text{ lb/day} = 98.4 \text{ days}$$

Takes 10 days to deliver plus 2 days of weekend

$$\text{Therefore, day to operate before ordering} = 98.4 \text{ days} - 12 \text{ days} = \mathbf{86.4 \text{ days}}$$

5. If your daily flow changes to 3.3 MGD, what should your feeder setting be in %?

$$\frac{61.8\%}{X} = \frac{2.9 \text{ MGD}}{3.3 \text{ MGD}}$$

$$(2.9 \text{ MGD}) X = (61.8\%) (3.3 \text{ MGD})$$

$$X = \frac{(61.8\%) (3.3 \text{ MGD})}{(2.9 \text{ MGD})} = \frac{203.94\%}{2.9} = \mathbf{70.3\%}$$

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1 (CONTINUED)

6. As a Class IV certified operator you have been asked by the Mayor and city council to provide them with a projected annual operating budget (rounded to the nearest \$100) for chlorination at a booster pump station.

DATA:

The booster pumps run on a continuous 12 hour alternating cycle (both pumps identical). The pump is 150 HP, with an efficiency of 72%, pumping into a 18 inch D.I. pipe. The elevation of the pumps is 4089 feet and the reservoir they are pumping to is 4356 feet (floor). The tank is 155 feet in diameter with an overflow at 30 feet, above the floor. The chlorine demand is 1.0 mg/L with a required free chlorine residual 0.6 mg/L and the cost of chlorine is 47 cents per pound.

$$\text{Dose (mg/L)} = \text{Demand (mg/L)} + \text{Residual (mg/L)}$$

$$\text{Dose (mg/L)} = 1.0 \text{ mg/L} + 0.6 \text{ mg/L}$$

$$\text{Dose (mg/L)} = 1.6 \text{ mg/L}$$

$$\text{Head (ft)} = 4356 \text{ ft} - 4089 \text{ ft} = 267 \text{ ft}$$

$$Q \text{ (gpm)} = \frac{(3956) \cdot \text{HP}}{\text{Head (ft)} \cdot (\text{Sp.Grav})}$$

$$Q \text{ (gpm)} = \frac{(3956)(150)}{(267 \text{ ft})(1)} = \frac{593,400 \text{ gpm}}{267} = 2222.47 \text{ gpm}$$

$$Q \text{ (MGD)} = \frac{(2222.47 \text{ gpm})}{694.4 \text{ gpm}} \times (1 \text{ MG}) =$$

$$Q \text{ (MGD)} = 3.20 \text{ MGD}$$

$$\frac{3.2 \text{ MGD}}{X} = \frac{100\%}{72\%}$$

$$(100\%)(X) = (3.20 \text{ MGD})(72\%)$$

$$X = \frac{(3.2 \text{ MGD})(72\%)}{100\%} = 2.3 \text{ MGD}$$

$$\text{Feed (lb/day)} = [\text{Dose (mg/L)}] \times [\text{Flow (MGD)}] \times [8.34 \text{ lb/gal}]$$

$$\text{Feed (lb/day)} = (1.6 \text{ mg/L}) \times (2.3 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = 30.75 \text{ lb/day}$$

$$\text{Feed (lb/year)} = \frac{(30.75 \text{ lb}) \times (365 \text{ days})}{(1 \text{ day}) \times (1 \text{ year})} = 11,334 \text{ lb/year}$$

$$\text{Cost} = (11,334 \text{ lb/year}) (\$0.47/\text{lb}) = \$5,326.98/\text{year}$$

Therefore, the closest choice within \$100 is **\$5,300**.

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1 (CONTINUED)

7. Your treatment plant is feeding a dry polymer mixed in a barrel with water and pumped to the injection point. You are mixing 2 lbs. into 500 gal. of water. From testing you have determined the dose needed to be 0.8 ppm. Your pump is calibrated to feed 35 L/min at 100% and you are currently treating 0.5 MGD. What should your pump setting be in % and L/min?

$$\text{Feed (lb/day)} = [\text{Dose (mg/L)}] \times [\text{Flow (MGD)}] \times [8.34 \text{ lb/gal}]$$

$$\text{Feed (lb/day)} = (0.8 \text{ mg/L}) \times (0.5 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = 3.336 \text{ lb/day}$$

$$\frac{(3.336 \text{ lb})}{(1 \text{ day})} \times \frac{(500 \text{ gal})}{(2 \text{ lbs})} = \frac{(500) \times (3.336) \text{ gal}}{2 \text{ day}} = 834 \text{ gal/day}$$

$$\frac{(834 \text{ gal})}{(1 \text{ day})} \times \frac{(3.785 \text{ L})}{(1 \text{ gal})} \times \frac{(1 \text{ day})}{(1440 \text{ min})} = 2.19 \text{ L/min}$$

$$\frac{100 \%}{X} = \frac{35 \text{ L/min}}{2.19 \text{ L/min}}$$

$$35 \text{ L/min (X)} = (100\%)(2.19 \text{ L/min})$$

$$X = \frac{(100\%)(2.19 \text{ L/min})}{35 \text{ L/min}} = \frac{219\%}{35} = 6.26\%$$

Therefore, the pump setting should be **2.2 L/min at 6.3 %**.

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1 (CONTINUED)

8. 15% sodium hypochlorite yields 1.25 lbs of chlorine per gallon. The sodium hypochlorite delivered to you has a certificate of analysis result and tests to be 14.2%. You are currently treating 2.08 MGD and your chlorine demand is 4.2 mg/L. Your sodium hypochlorite pump is calibrated to feed 1.6 gpm at 100% speed setting. You want an effluent chlorine residual of 1.5 mg/L. What should your sodium hypochlorite pump speed setting be in %?

$$\text{Dose (mg/L)} = \text{Demand (mg/L)} + \text{Residual (mg/L)}$$

$$\text{Dose (mg/L)} = 4.2 \text{ mg/L} + 1.5 \text{ mg/L}$$

$$\text{Dose (mg/L)} = 5.7 \text{ mg/L}$$

$$\text{Feed (lb/day)} = \text{Dose (mg/L)} \times \text{Flow (MGD)} \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = (5.7 \text{ mg/L}) \times (2.08 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = 98.88 \text{ lb/day}$$

$$\frac{1.25 \text{ lbs}}{X} = \frac{15\%}{14.2\%}$$

$$15\%(X) = (1.25 \text{ lbs})(14.2\%)$$

$$X = \frac{(1.25 \text{ lbs})(14.2\%)}{15\%}$$

$$X = 1.18 \text{ lbs}$$

$$\frac{98.88 \text{ lb/day}}{\text{day}} \times \frac{1 \text{ gal}}{1.18 \text{ lbs}} = 83.8 \text{ lb/day}$$

$$\frac{(83.8 \text{ lb}) \times (1 \text{ day})}{(1 \text{ day}) \times (1440 \text{ min})} = 0.058 \text{ gpm}$$

$$\frac{100\%}{X} = \frac{1.6 \text{ gpm}}{0.058 \text{ gpm}}$$

$$1.6 \text{ gpm}(X) = (0.058 \text{ gpm})(100\%)$$

$$X = \frac{(0.058 \text{ gpm})(100\%)}{(1.6 \text{ gpm})} = \frac{5.8\%}{1.6} = 3.625\%$$

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1 (CONTINUED)

9. A rectangular sedimentation basin is 40 feet long, 55 feet wide, 18 feet deep and treats a flow of 2.4 MGD. Determine the loss in detention time in minutes if the basin contains 7 feet of sludge.

$$\begin{aligned}V (\text{gal}) &= l (\text{ft}) \times w (\text{ft}) \times h (\text{ft}) \times (7.48 \text{ gal/ft}^3) \\V (\text{gal}) &= (40 \text{ ft}) \times (55 \text{ ft}) \times (7 \text{ ft}) \times (7.48 \text{ gal/ft}^3) \\V (\text{gal}) &= (115,192 \text{ gal}) \times \frac{(1 \text{ MG})}{(1,000,000 \text{ gal})} = 0.115 \text{ MG}\end{aligned}$$

$$\begin{aligned}\text{D.T. (min)} &= \text{Vol (MG)} / \text{Flow (MGD)} \\ \text{D.T.} &= \frac{(0.115 \text{ MG})}{(2.4 \text{ MGD})} \times \frac{(1440 \text{ min})}{(1 \text{ day})} = \frac{165.6 \text{ min}}{2.4} = \mathbf{69.1 \text{ min}}\end{aligned}$$

10. Liquid alum delivered to a water plant contains 547.8 mg/mL of liquid solution. Jar tests indicate that the best alum dose is 5 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the flow is 1.95 MGD.

$$\begin{aligned}\text{Feed (lb/day)} &= \text{Dose (mg/L)} \times \text{Flow (MGD)} \times (8.34 \text{ lb/gal}) \\ \text{Feed (lb/day)} &= (5 \text{ mg/L}) \times (1.95 \text{ MGD}) \times (8.34 \text{ lb/gal}) \\ \text{Feed (lb/day)} &= 81.32 \text{ lb/day}\end{aligned}$$

$$\frac{(81.32 \text{ lb})}{(1 \text{ day})} \times \frac{(1 \text{ day})}{(1440 \text{ min})} \times \frac{(453.59 \text{ gram})}{(1 \text{ lb})} \times \frac{(1000 \text{ mg})}{(1 \text{ gram})} = \frac{36,885,938 \text{ mg}}{1440 \text{ min}} = 25,615.23 \text{ mg/min}$$

$$\frac{25,615.23 \text{ mg/min}}{547.8 \text{ mg/ml}} = 46.76 \text{ ml/min} \sim \mathbf{47 \text{ ml/min}}$$

11. A reaction basin 12 ft. in diameter and 14 ft. deep was added to the existing basin 35 ft. in diameter and 10 ft. deep. What is the maximum flow in MGD that will allow a 30 minute detention time?

$$\begin{aligned}V_1 &= 0.785d^2h \times (7.48 \text{ gal/ft}^3) \\ V_1 &= (0.785) \times (12 \text{ ft}) \times (12 \text{ ft}) \times (14 \text{ ft}) \times (7.48 \text{ gal/ft}^3) \\ V_1 &= 11,837.55 \text{ gal} \\ V_2 &= 0.785d^2h \times (7.48 \text{ gal/ft}^3) \\ V_2 &= (0.785) \times (35 \text{ ft}) \times (35 \text{ ft}) \times (10 \text{ ft}) \times (7.48 \text{ gal/ft}^3) \\ V_2 &= 71,929.55 \text{ gal}\end{aligned}$$

$$\begin{aligned}V &= V_1 + V_2 \\ V &= 11,837.55 \text{ gal} + 71,929.55 \text{ gal} \\ V &= 83,767.1 \text{ gal} \times \frac{(1 \text{ MG})}{1,000,000 \text{ gal}} = 0.084 \text{ MG}\end{aligned}$$

$$Q (\text{MGD}) = \frac{\text{Vol (MG)}}{\text{DT (min)}} = \frac{0.084 \text{ MG} \times 1440 \text{ min}}{30 \text{ min} \times 1 \text{ day}} = \frac{120.96 \text{ MG}}{30 \text{ day}} = \mathbf{4.03 \text{ MGD}}$$

APPENDIX E - ANSWERS TO CLASS IV – PRACTICE #1 (CONTINUED)

12. Your water system is required to take 30 first-draw samples for lead. The lab analysis shows the following:

3 samples at 0.005 mg/L	2 sample at 0.030 mg/L
1 samples at 0.010 mg/L	6 samples at 0.017 mg/L
3 samples at 0.015 mg/L	9 samples at <0.002 mg/L
1 sample at 0.020 mg/L	4 samples at 0.007 mg/L
1 sample at 0.025 mg/L	

What is the 90th percentile of the lead level?

$$90^{\text{th}} \text{ Percentile} = (30 \text{ samples}) \times (0.90) = 27$$

30 0.030 mg/L

29 0.030 mg/L

28 0.025 mg/L

27 0.020 mg/L

Therefore, the 90th percentile for lead is **0.020 mg/L**.

13. A polymer pump is calibrated by timing to deliver 650 mL in 30 seconds. How much coagulant is being added in gpm?

$$\frac{(650 \text{ mL}) (60 \text{ sec})(1 \text{ L})(1 \text{ gallon})}{(30 \text{ sec}) (1 \text{ min})(1000\text{mL})(3.785\text{L})} = \frac{39,000 \text{ gal}}{113,550 \text{ min}} = \mathbf{0.34 \text{ gpm}}$$

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2

Use the following information to answer the following questions. Your water treatment plant uses potassium permanganate to oxidize iron and manganese from the raw water. The plant processes are traditional, complete treatment with greensand filters.

potassium permanganate dose = $\{2 \times (\text{raw Mn, mg/L})\} + \text{raw Fe, mg/L} + \text{desired residual}$

potassium permanganate in inventory = 21,000 lbs.

calibration beaker weight = 450 g

plant flow = 3.9 MGD

raw water manganese = 1.6 mg/L

raw water iron = 0.6 mg/L

chemical supplier does not work on Saturday or Sunday

a single bulk delivery cannot exceed 35,000 lbs

desired permanganate residual = 0.1 mg/L

price for a full bulk delivery = \$3,220.00/ton

time required from order to delivery = 10 working days

price for deliveries under 12,000 lbs = \$3,000.00/ton

Dry Feeder Output per 15 minute grab sample

Setting	Sample weight including beaker
30%	775 grams
50%	992 grams
70%	1248 grams

1. What is your potassium permanganate dose in lbs/day?

Dose (mg/L) = $2(\text{raw Mn}) + \text{raw Fe} + \text{desired Residual}$

Dose (mg/L) = $2(1.6 \text{ mg/L}) + 0.6 \text{ mg/L} + 0.1 \text{ mg/L}$

Dose (mg/L) = $3.2 \text{ mg/L} + 0.6 \text{ mg/L} + 0.1 \text{ mg/L}$

Dose (mg/L) = 3.9 mg/L

Feed (lb/day) = $[\text{Dose (mg/L)}] \times [\text{Q (MGD)}] \times [8.34 \text{ lb/gal}]$

Feed (lb/day) = $(3.9 \text{ mg/L}) (3.9 \text{ MGD}) (8.34 \text{ lb/gal})$

Feed (lb/day) = **126.85 lb/day**

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2 (CONTINUED)

2. What is the dry feeder calibration results? (setting in %)

30 % yields

$$775 \text{ g} - 450 \text{ g} = 325 \text{ g} \times \frac{1 \text{ lb}}{454 \text{ g}} = \frac{0.72 \text{ lbs} \times 60 \text{ min} \times 24 \text{ hr}}{15 \text{ min} \times 1 \text{ hr} \times 1 \text{ day}} = \frac{1,030.63 \text{ lbs}}{15 \text{ day}} = 68.7 \text{ lbs/day}$$

50 % yields

$$992 \text{ g} - 450 \text{ g} = 542 \text{ g} \times \frac{1 \text{ lb}}{454 \text{ g}} = \frac{1.19 \text{ lbs} \times 60 \text{ min} \times 24 \text{ hr}}{15 \text{ min} \times 1 \text{ hr} \times 1 \text{ day}} = \frac{1,719.12 \text{ lbs}}{15 \text{ day}} = 114.6 \text{ lbs/day}$$

70 % yields

$$1248 \text{ g} - 450 \text{ g} = 798 \text{ g} \times \frac{1 \text{ lb}}{454 \text{ g}} = \frac{1.76 \text{ lbs} \times 60 \text{ min} \times 24 \text{ hr}}{15 \text{ min} \times 1 \text{ hr} \times 1 \text{ day}} = \frac{2,534.4 \text{ lbs}}{15 \text{ day}} = 169 \text{ lbs/day}$$

$$\frac{50 \%}{X} = \frac{115 \text{ lbs/day}}{127 \text{ lbs/day}}$$

$$115 \text{ lbs/day} (X) = (127 \text{ lbs/day}) (50\%)$$

$$X = \frac{(127 \text{ lbs/day}) (50\%)}{115 \text{ lbs/day}} = \frac{6,350\%}{115} = 55.2\%$$

$$\frac{70 \%}{X} = \frac{169 \text{ lbs/day}}{127 \text{ lbs/day}}$$

$$169 \text{ lbs/day} (X) = (127 \text{ lbs/day}) (70\%)$$

$$X = \frac{(127 \text{ lbs/day}) (70\%)}{169 \text{ lbs/day}} = \frac{8,890\%}{169} = 52.6\%$$

$$\frac{55.2 \% + 52.6\%}{2} = \frac{107.8\%}{2} = \mathbf{53.9\%}$$

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2 (CONTINUED)

3. What is the projected cost (to the nearest hundred) for potassium permanganate for a 12 month period?

$$\frac{(126.85 \text{ lb})}{(1 \text{ day})} \times (365 \text{ days}) = 46,300.25 \text{ lb.}$$

$$46,300 - 35,000 \text{ lbs per bulk} = 11,300 \text{ lbs per partial load}$$

$$35,000 \text{ lbs} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = 17.5 \text{ ton} \times \frac{\$3220}{\text{ton}} = \$56,350$$

$$11,300 \text{ lbs} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = 5.65 \text{ ton} \times \frac{\$3000}{\text{ton}} = \$16,950$$

$$\$56,350 + \$16,950 = \text{\$73,300/12 months}$$

4. How many days can you operate before you must place an order for a full bulk load?

$$35,000 \text{ lb} \div 126.85 \text{ lb/day} = 275.92 \text{ days}$$

Takes 10 days to deliver plus 2 days of weekend

$$\text{Therefore, day to operate before ordering} = 276 \text{ days} - 12 \text{ days} = \textbf{264 days}$$

5. If your daily flow changes to 2.9 MGD, what should your feeder setting be in %?

$$\frac{53.9 \%}{X} = \frac{3.9 \text{ MGD}}{2.9 \text{ MGD}}$$

$$(3.9 \text{ MGD}) X = (53.9\%) (2.9 \text{ MGD})$$

$$X = \frac{(53.9\%) (2.9 \text{ MGD})}{(3.9 \text{ MGD})} = \frac{156.31\%}{3.9} = \textbf{40.1\%}$$

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2 (CONTINUED)

6. As the Chief Operator you have been asked by the Mayor and city council to provide them with a projected annual operating budget (rounded to the nearest \$100) for chlorination at a booster pump station.

DATA: The booster pumps run on a continuous 12 hour alternating cycle (both pumps identical). The pump is 125 HP, with an efficiency of 82%, pumping into a 18 inch D.I. pipe. The elevation of the pumps is 4118 feet and the reservoir they are pumping to is 4356 feet (floor). The tank is 155 feet in diameter with an overflow at 25 feet, above the floor. The chlorine demand is 1.3 mg/L with a required free chlorine residual 0.6 mg/L and the cost of chlorine is 43 cents per pound.

$$\text{Dose (mg/L)} = \text{Demand (mg/L)} + \text{Residual (mg/L)}$$

$$\text{Dose (mg/L)} = 1.3 \text{ mg/L} + 0.6 \text{ mg/L}$$

$$\text{Dose (mg/L)} = 1.9 \text{ mg/L}$$

$$\text{Head (ft)} = 4356 \text{ ft} - 4118 \text{ ft} = 238 \text{ ft}$$

$$Q \text{ (gpm)} = \frac{(3956) \cdot \text{HP}}{\text{Head (ft)} \cdot (\text{Sp.Grav})}$$

$$Q \text{ (gpm)} = \frac{(3956) (125)}{(238 \text{ ft}) (1)} = \frac{494,500 \text{ gpm}}{238} = 2077.73 \text{ gpm}$$

$$Q \text{ (MGD)} = \frac{2077.73 \text{ gpm}}{694.4 \text{ gpm}} \times (1 \text{ MG}) =$$

$$Q \text{ (MGD)} = 2.99 \text{ MGD}$$

$$\frac{2.99 \text{ MGD}}{X} = \frac{100\%}{82\%}$$

$$(100\%)(X) = (2.99 \text{ MGD})(82\%)$$

$$X = \frac{(2.99 \text{ MGD})(82\%)}{100\%} = 2.45 \text{ MGD}$$

$$\text{Feed (lb/day)} = \text{Dose (mg/L)} \times \text{Flow (MGD)} \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = (1.9 \text{ mg/L}) \times (2.45 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = 38.82 \text{ lb/day}$$

$$\text{Feed (lb/year)} = \frac{(38.82 \text{ lb}) \times (365 \text{ days})}{(1 \text{ day}) \times (1 \text{ year})}$$

$$\text{Feed (lb/year)} = 14,169.3 \text{ lb/year}$$

$$\text{Cost} = (14,169.3 \text{ lb/year}) \times (\$0.43/\text{lb}) = \$6,092.80/\text{year}$$

Therefore, the closest choice within \$100 is **\$6,100**.

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2 (CONTINUED)

7. Your treatment plant is feeding a dry polymer mixed in a barrel with water and pumped to the injection point. You are mixing 2.5 lbs. into 500 gal. of water. From testing you have determined the dose needed to be 0.75 ppm. Your pump is calibrated to feed 25 L/min at 100% and you are currently treating 0.45 MGD. What should your pump setting be in % and L/min?

$$\text{Feed (lb/day)} = \text{Dose (mg/L)} \times \text{flow (MGD)} \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = (0.75 \text{ mg/L}) \times (0.45 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = 2.81 \text{ lb/day}$$

$$\frac{(2.81 \text{ lb})}{(1 \text{ day})} \times \frac{(500 \text{ gal})}{(2 \text{ lbs})} = \frac{500 \text{ gal} \times 2.81 \text{ lbs}}{2 \text{ day}} = 703.7 \text{ gal/day}$$

$$\frac{(703.7 \text{ gal})}{(1 \text{ day})} \times \frac{(3.785 \text{ L})}{(1 \text{ gal})} \times \frac{(1 \text{ day})}{(1440 \text{ min})} = \frac{2,663.5 \text{ L}}{1440 \text{ min}} = 1.85 \text{ L/min}$$

$$\frac{100 \%}{X} = \frac{25 \text{ L/min}}{1.85 \text{ L/min}}$$

$$25 \text{ L/min (X)} = (100\%)(1.85 \text{ L/min})$$

$$X = \frac{(100\%)(1.85)}{25} = \frac{185\%}{25} = 7.4\%$$

Therefore, the pump setting should be **1.9 L/min at 7.4%.**

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2 (CONTINUED)

8. 15% sodium hypochlorite yields 1.25 lbs of chlorine per gallon. The sodium hypochlorite delivered to you has a certificate of analysis result and tests to be 14.4%. You are currently treating 1.48 MGD and your chlorine demand is 3.2 mg/L. Your sodium hypochlorite pump is calibrated to feed 1.9 gpm at 100% speed setting. You want an effluent chlorine residual of 1.4 mg/L. What should your sodium hypochlorite pump speed setting be in %?

$$\text{Dose (mg/L)} = \text{Demand (mg/L)} + \text{Residual (mg/L)}$$

$$\text{Dose (mg/L)} = 3.2 \text{ mg/L} + 1.4 \text{ mg/L}$$

$$\text{Dose (mg/L)} = 4.6 \text{ mg/L}$$

$$\text{Feed (lb/day)} = \text{Dose (mg/L)} \times \text{Flow (MGD)} \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = (4.6 \text{ mg/L}) \times (1.48 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = 56.78 \text{ lb/day}$$

$$\frac{1.25 \text{ lbs}}{X} = \frac{15\%}{14.4\%}$$

$$15\%(X) = (1.25 \text{ lbs})(14.4\%)$$

$$X = \frac{(1.25 \text{ lbs})(14.4\%)}{15\%} = \frac{18 \text{ lbs}}{15} = 1.2 \text{ lbs}$$

$$\frac{56.78 \text{ lb/day}}{\text{day}} \times \frac{1 \text{ gal}}{1.2 \text{ lbs}} = 47.3 \text{ lb/day}$$

$$\frac{(47.3 \text{ lb})}{(1 \text{ day})} \times \frac{(1 \text{ day})}{(1440 \text{ min})} = 0.033 \text{ gpm}$$

$$\frac{100\%}{X} = \frac{1.9 \text{ gpm}}{0.033 \text{ gpm}}$$

$$1.9 \text{ gpm}(X) = (0.033 \text{ gpm})(100\%)$$

$$X = \frac{(0.033 \text{ gpm})(100\%)}{(1.9 \text{ gpm})} = \frac{3.4\%}{1.9} = \mathbf{1.74\%}$$

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2 (CONTINUED)

9. A rectangular sedimentation basin is 42 feet long, 45 feet wide, 28 feet deep and treats a flow of 1.97 MGD. Determine the loss in detention time in minutes if the basin contains 11 feet of sludge.

$$V \text{ (gal)} = l \text{ (ft)} \times w \text{ (ft)} \times h \text{ (ft)} \times (7.48 \text{ gal/ft}^3)$$

$$V \text{ (gal)} = (42 \text{ ft}) \times (45 \text{ ft}) \times (11 \text{ ft}) \times (7.48 \text{ gal/ft}^3)$$

$$V \text{ (gal)} = (155,509 \text{ gal}) \times \frac{(1 \text{ MG})}{(1,000,000 \text{ gal})} = 0.156 \text{ MGD}$$

$$\text{D.T.} = \frac{\text{Vol (MG)}}{\text{Flow (MGD)}} = \frac{(0.156 \text{ MG})}{(1.97 \text{ MGD})} \times \frac{(1440 \text{ min})}{(1 \text{ day})} = \frac{224.64 \text{ min}}{1.97} = \mathbf{114 \text{ min}}$$

10. Liquid alum delivered to a water plant contains 357.8 mg/mL of liquid solution. Jar tests indicate that the best alum dose is 7 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the flow is 1.23 MGD.

$$\text{Feed (lb/day)} = \text{Dose (mg/L)} \times \text{Flow (MGD)} \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = (7 \text{ mg/L}) \times (1.23 \text{ MGD}) \times (8.34 \text{ lb/gal})$$

$$\text{Feed (lb/day)} = 71.81 \text{ lb/day}$$

$$\frac{(71.81 \text{ lb})}{(1 \text{ day})} \times \frac{(1 \text{ day})}{(1440 \text{ min})} \times \frac{(454 \text{ gram})}{(1 \text{ lb})} \times \frac{(1000 \text{ mg})}{(1 \text{ gram})} = \frac{32,601,740 \text{ mg}}{1440 \text{ min}} = 22,640 \text{ mg/min}$$

$$\frac{22,640 \text{ mg/min}}{357.8 \text{ mg/mL}} = \mathbf{63.3 \text{ mL/min}}$$

11. A reaction basin 15 ft. in diameter and 16 ft. deep was added to the existing basin 15 ft. in diameter and 19 ft. deep. What is the maximum flow in MGD that will allow a 30 minute detention time?

$$V_1 = 0.785d^2h \cdot (7.48 \text{ gal/ft}^3)$$

$$V_1 = (0.785) \times (15 \text{ ft}) \times (15 \text{ ft}) \times (16 \text{ ft}) \times (7.48 \text{ gal/ft}^3)$$

$$V_1 = 21,138.48 \text{ gal}$$

$$V_2 = 0.785d^2h \cdot (7.48 \text{ gal/ft}^3)$$

$$V_2 = (0.785) \times (15 \text{ ft}) \times (15 \text{ ft}) \times (19 \text{ ft}) \times (7.48 \text{ gal/ft}^3)$$

$$V_2 = 25,101.95 \text{ gal}$$

$$V = V_1 + V_2$$

$$V = 21,138.48 \text{ gal} + 25,101.95 \text{ gal}$$

$$V = 46,240.43 \text{ gal} \times \frac{1 \text{ MG}}{1,000,000 \text{ gal}} = 0.046 \text{ MG}$$

$$\text{Flow (MGD)} = \frac{\text{Vol (MG)}}{\text{DT (day)}} = \frac{(0.046 \text{ MG})}{(30 \text{ min})} \times \frac{(1440 \text{ min})}{(1 \text{ day})} = \frac{66.24 \text{ MG}}{30 \text{ day}} = \mathbf{2.21 \text{ MD}}$$

APPENDIX F- ANSWERS TO CLASS IV – PRACTICE #2 (CONTINUED)

12. Your water system is required to take 50 first-draw samples for lead. The lab analysis shows the following:

3 samples at 0.005 mg/L	2 sample at 0.030 mg/L
1 samples at 0.010 mg/L	6 samples at 0.017 mg/L
3 samples at 0.015 mg/L	9 samples at <0.002 mg/L
1 sample at 0.020 mg/L	4 samples at 0.007 mg/L
1 sample at 0.025 mg/L	

What is the 90th percentile of the lead level?

$$90^{\text{th}} \text{ Percentile} = (50 \text{ samples}) (0.90) = 45$$

50	0.030 mg/L
49	0.030 mg/L
48	0.025 mg/L
47	0.020 mg/L
46	0.017 mg/L
45	0.017 mg/L

Therefore, the 90th percentile for lead is **0.017 mg/L**.

13. A polymer pump is calibrated by timing to deliver 456 mL in 25 seconds. How much coagulant is being added in gpm?

$$\frac{(456 \text{ mL}) (60 \text{ sec})(1 \text{ L})(1 \text{ gallon})}{(25 \text{ sec}) (1 \text{ min})(1000\text{mL})(3.785\text{L})} = \frac{27,360 \text{ gal}}{94,625 \text{ min}} = \mathbf{0.29 \text{ gpm}}$$