ADVANCED MATH HANDBOOK

For Class III & IV Water Operators

2011

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, along with your operating experience and common sense, should help you pass the 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. But learning the math does not have to be that difficult.

1. Watch what you tell yourself.

Many times operators have told me, “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 supper. 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.

5. 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. 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.

WATER OPERATOR EXAM FORMULA SHEET Rev. 10/2010

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 = 1,440 minutes	gpd = gallon per day
1 gallon = 8.34 pounds	1 day = 24 hours	MGD = million gallons per day
1 gallon = 3.785 liters	1 lb = 454 grams	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 gpg = 17.12 mg/L	1 gpd = 2.63 mL/min
π(pi) = 3.14	Sp. Gr = specific gravity	Specific gravity (water) = 1.00
W/W = weight/weight	W/V = weight/volume	1 ac-ft = 43,560 cu ft

TEMPERATURE

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

CIRCUMFERENCE, AREA & VOLUME

Circumference (C, ft) = π x diameter (D, ft)

Area of a rectangle (A, sq ft) = (length, ft) x (width, ft)
Area of a circle (A, sq ft) = 0.785 x $(\text{diameter, ft})^2$
Area of a circle (A, sq ft) = π x $(\text{radius, ft})^2$

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

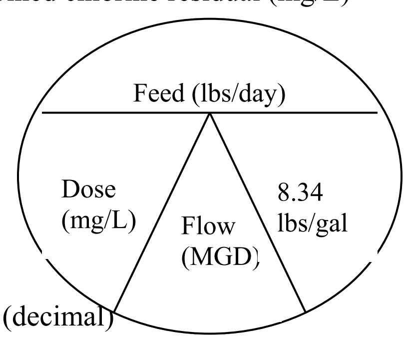
Volume of a cylinder (V, cu ft) = 0.785 x $(\text{diameter, ft})^2$ x (height, ft)
Volume of a cylinder (V, gal) = 0.785 x $(\text{diameter, ft})^2$ x (height, ft) x 7.48 gal/cu ft

CHLORINATION

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

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

POUNDS, DOSAGE & FLOW



Dose (mg/L) = Feed (lbs/day) ÷ flow (MGD) ÷ (8.34 lbs/gal)

Flow (MGD) = Feed (lbs/day) ÷ dose (mg/L) ÷ (8.34 lbs/gal)

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

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

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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

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

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

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

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

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

MISC

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

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

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

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CHEMICAL DOSES

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

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

Calibration of Solution

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

FILTRATION

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

Unit Filter Rate Volume (UFRV) = (Filtration Rate, gpm/sq ft)(Filter Run, hr)(60 min/hr)

Backwash Water, gal = (Backwash Flow, gpm)(Backwash Time, min)

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

CORROSION CONTROL

$$pH_s = A + B + \log(Ca^{2+}) + \log(Alk)$$

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

COAGULATION AND FLOCCULATION

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

DISINFECTION

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

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

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

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

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

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HORSEPOWER

$$\text{Flow (Q, gpm)} = \frac{(3{,}956) \times \text{HP}}{\text{Head (ft)} \times \text{(Sp.Grav)}}$$

$$\text{Water, HP} = \frac{\text{Flow (Q, gpm)} \times \text{Head (ft)} \times 8.34 \text{ lbs/gal}}{33{,}000 \text{ ft-lbs/min-HP}}$$

$$\text{kW hour} = \text{(HP)} \times \text{(hours/day)} \times (0.746 \text{ kW/HP})$$

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

SPECIFIC GRAVITY & DENSITY

$$\text{Density} = \frac{\text{weight of substance}}{\text{volume of substance}}$$

$$\text{Specific gravity} = \frac{\text{density of substance}}{\text{density of water}}$$

$$\text{Specfic gravity} = \frac{\text{weight of substance}}{\text{weight of an equal volume of water}}$$

Weight of substance = Sp. Gr. x weight of water

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 EXAM PREPARATION

1. The analytical results of the lead content of your water supply show the following results:

   0.005 mg/L, 0.020 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L

   What is the 90th percentile for lead content?

2. What is the average fluoride reading over the past week: 0.91 mg/L, 0.75 mg/L, 0.84 mg/L, 1.22 mg/L, 0.98 mg/L, 1.07 mg/L?

3. A water sample has the following results:
   Bromodichloromethane 0.005 mg/L,
   Chloroform 0.035 mg/L,
   Bromoform 0.002 mg/L,
   Dibromochloromethane 0.006mg/L.

   What is the total of trihalomethanes?

4. Convert 70°F is what in Celsius?

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

6. In 25 pounds of 70 percent calcium hypochlorite there are how many pounds of available chlorine:

7. In water treatment, 17,500 mg/L is considered to be equivalent to:

8. Convert 6.6 grains per gallon to mg/L of hardness:

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

10. What is the chlorine demand if the water has a chlorine dose of 5.2 mg/L and the residual is 0.5 mg/L?

11. How many pounds of chlorine gas are required to treat 200 gpm of water to provide a 1.8 mg/L residual?

12. A clearwell is 12 ft deep, 15 ft wide, and 30 feet long. If the flow through the clearwell is 0.25 MGD, what is the detention time in hours?

13. A chlorinator is set to feed 40 pounds of chlorine in 24 hours to a flow of 1.05 MGD. Find the chlorine dose in mg/L.

14. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 8-inch diameter water line 12,000 feet long using dosage of 50 mg/L chlorine?

15. The average chlorine residual entering a booster station is 0.8 mg/L. Using a gas chlorine feed system on site, the operator must boost the chlorine to a residual of 2.5 mg/L. The

booster pump will run 12 hours per day at a rate 0.25 MGD. How many pounds of Cl_2 will be fed per day?

16. A clearwell is 16 ft deep, 12 ft wide, and 25 feet long. If the flow through the clearwell is 0.50 MGD, what is the detention time in hours?

17. A water plant uses 15 gallons of sodium fluoride solution in treating 0.35 MGD of water. Natural fluoride ion is 0.15 mg/L. What is the calculated dosage?

18. A rectangular reservoir 95 ft x 40 ft x 15 ft is filled with water. How many pounds of chemical must be added in order to produce a dosage of 50 mg/L?

19. What amount of 100% chlorine is required to treat 2.5 million gallons of water to provide a 1 mg/L dose?

20. A container weighing 51 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 105 grams after 2 minutes. What is the dosage in lbs/day?

21. Water from a well is being treated by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 10 gpd and uses a 12% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 250 gpm?

22. A chemical pump is calibrated by timing to deliver 560 milliliter in 15 seconds. How much chemical is being added in gallons per minute?

23. A diaphragm pump feeds a polyphosphate to the clearwell to treat for iron and manganese. At 100% the pump will put out 200 mL per min. The operator must treat a plant flow of 0.50 MGD with 4.5 mg/L of polyphosphate. The polyphosphate weighs approximately 12 lbs/gallon. What is the pump setting?

24. A water treatment plant used 47 chlorine cylinders during one year of operation. The average withdrawal from each cylinder was 146 lbs. What was the total number of pounds of chlorine used for the year?

25. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 200,000 gallons of water. The raw water has a natural fluoride content of 0.25 mg/L and the desired fluoride in the finished water is 1.0 mg/L. How many gallons of feed solution is needed?

26. Examination of the raw water shows manganese levels of 0.6 mg/L and total iron levels of 0.3 mg/L. How many pounds of potassium permanganate should be fed to treat 300,000 gallons per day for only iron and manganese?

27. The elevation of water in the tank is at 1,450 feet, the elevation of the pump is 520 feet. What is the gauge pressure at the pump?

28. Your utility is laying 5,000 feet of 8 inch main to a remote area of your distribution system. Average flow to this area is expected to be 0.02 MGD. What will be the average detention time (in days) for water in 8" main?

29. Find the detention time in hours in a tank that measures 55 ft. long by 35 ft. wide and 20 ft. deep with a flow to the tank of 2,000 gpm.

30. If a 100 foot tall tank with a 25 foot diameter contains 68 feet of water, calculate the volume of water in gallons.

31. A distribution booster station operates 12 hours per day. The system requires that the water must be re-chlorinated and expects to use 15 lbs of Cl_2 per day. The booster station pumps 500 gpm. The operator should set the chlorine feed rate at:

32. How many hours would it take to use the water in a 75,000 ft. 8 inch pipe with an outflow of 2,000 gpm in an inflow of 500 gpm?

33. If chlorine costs $0.38/lb, what is the daily cost to chlorinate 2.5 MGD of water to an initial concentration of 1.6 mg/L?

34. During a 30 day period a booster station pumped 35,250 gallons of water to an isolated pressure zone. During the same period the customers of the zone were billed for a total of 28,300 gallons of water used. Also during this period the high service pumps produced 5,200,000 gallons into the distribution system. What is the water loss percentage for the pressure zone?

35. Last month your Water System pumped 5,226,300 gallons of water into the distribution system. Your system was able to account for 2,964,800 gallons. What was your unaccounted for % of water for this month?

36. A water system bills at a rate of $0.55/1,000 gallons for the first 10,000 gallons; $0.30/1,000 gallons for the next 15,000 gallons; and $0.15/1,000 gallons for all over 25,000 gallons. If a customer uses 43,000 gallons. How much is the water bill?

37. At the beginning of a day, the master meter reading was 261,289 gallons. The next morning, the master meter reading was 462,006 gallons. The daily flow during the 24-hour period was approximately ___ MGD.

38. Your system is preparing to apply for a rate increase and the PSC is asking about your "unaccounted for water" for the month of July. Your plant produced 1.82 MG in July and the meter readings indicate 1.03 MG was billed. You have been informed that the fire department hauled 75,000 gallons to farmers and the hydrant flushing program used 25,000 gallons. What would you report as the unaccounted for water?

CLASS II EXAM PREPARATION

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

2. Convert 20 grains per gallons to mg/L of hardness.

3. Convert 111 mg/L to grains per gallons.

4. What is the smallest size pump that is needed to produce twice the daily average of 153,750 gpd?

5. A ferric chloride pump is calibrated by timing to deliver 870 milliliter in 15 seconds. How much coagulant is being added in gallons per minute?

6. The overflow of a water tank is located 145 feet above a neighborhood fire hydrant. Not accounting for c-factor of the pipe, what is the water pressure at the hydrant when the tank is full?

7. The bottom of a standpipe tank is 1,155 above sea level. The tank has a 30 feet diameter and stands 110feet tall and is 75% full. What is the pressure in pounds per square inch of standing water in the fire hydrant in a valley that has an elevation of 425 feet above sea level?

8. Convert 27°Celsius to Fahrenheit

9. A 100 milliliter sample is titrated with 0.02 M H2SO4. The endpoint is reached when 11.4 milliliters of H_2SO_4 have been added. The alkalinity concentration is:

10. A 50 milliliter sample is titrated with 0.01 M EDTA. The endpoint is reached when 11.4 milliliters of EDTA have been added. The hardness concentration is:

11. Calculate the 90^{th} percentile for lead using the following data: 0.033 mg/L, 0.011 mg/L, 0.003 mg/L, 0.004 mg/L, 0.023 mg/L.

12. What is the 90th percentile for lead in the following samples: 0.022 mg/L, 0.025 mg/L, 0.015 mg/L, 0.010 mg/L, 0.028 mg/L, 0.021 mg/L, 0.002 mg/L, <0.002 mg/L, <0.002 mg/L and 0.002 mg/L?

13. A water sample has the following results:
    Bromodichloromethane 0.005 mg/L,
    Chloroform 0.035 mg/L,
    Bromoform 0.002 mg/L,
    Dibromochloromethane 0.006mg/L.

    What is the total of trihalomethanes?

14. A water system analytical results indicates an iron level of 0.3 mg/L and a manganese level of 0.6 mg/L. Determine the estimated demand of potassium permanganate.

15. What is the minimum amount of water that will be needed to flush an 8 inch main that is 22,000 feet long for 30 minutes prior to disinfection and for 45 minutes after the water in line has been left standing for 6 hours? The water will pump at 750 gpm.

16. A water system has 2,500 feet of 8-inch mains, 6,500 feet of 6-inch mains, two storage tanks (50 feet in diameter and 128 feet high), and a 55'x 35'x 20' clearwell. How much water will be in the system when everything is full?

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

18. What is the minimum amount of water that will be used to disinfect a 8 inch main that is 12,800 feet long to 50 ppm <u>and</u> flush the main?

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

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

21. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 150,000 gallons of water. The raw water has a natural fluoride content of 0.45 mg/L and the desired fluoride in the finished water is 1.1 mg/L. How many gallons of feed solution is needed?

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

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

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

25. A filter that had been in service for 2 days, filtered 1.5 MG. If the filter is 12 feet wide by 18 feet in length, what was the average flow rate through the filter in gpm?

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

27. What is the dosage (of/where) 9 lbs of chlorine gas is added to 220,000 gallons of finished water?

28. How many pounds of HTH (65%) are needed to disinfect at 50 ppm a 8-inch diameter line that is 12,000 feet long?

29. Determine the setting on a potassium permanganate chemical feed pump in pounds per day if the demand is determined to be 1.6 ppm and a permanganate residual of 0.4 ppm and the flow is 0.45 MGD.

30. How many pounds of 65% HTH are needed to shock a 8 inch diameter pipe that is 12,000 feet long to 50 ppm of chlorine residual?

31. 0.1116 lb/min of soda ash is fed into 1,525,000 gal/day of treated water. What is the soda ash dosage?

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

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

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:

Volume (ft^3) = length (ft) x width (ft) x depth (ft)

Volume (gal) = length (ft) x width (ft) x depth (ft) x 7.48 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?

Volume (gal) = length (ft) x width (ft) x depth (ft) x 7.48 gal/ft^3
= 4 ft x 4 ft x 3 ft x 7.48 gal/ft^3
= 359 gal

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?

Volume (gal) = length (ft) x width (ft) x depth (ft) x 7.48 gal/ft^3
= 40 ft x 12 ft x 9 ft x 7.48 gal/ft^3
= 32,314 gal

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 in/(12 in/ft) = 0.5 ft

Volume (gal) = length (ft) x width (ft) x depth (ft) x 7.48 gal/ft^3
= 50 ft x 22 ft x 11.5 ft x 7.48 gal/ft^3
= 94,622 gal

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 min/day x 60 sec/min) = 69 gps

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

= 7.8 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 commonly used.

Tank Volume Calculations

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

For rectangular sedimentation tanks:

Vol (gal) = length(ft) x width (ft) x depth (ft) x 7,48 gal/ft^3

For cylindrical tanks:

Vol (gal) = 0.785 x D^2 x depth (ft) x 7,48 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/ft^2?

$$\text{Surface loading rate} = \frac{\text{flow (gpm)}}{\text{area (ft}^2\text{)}}$$

$$= \frac{1000 \text{ gpm}}{70 \text{ ft x } 25 \text{ ft}}$$

$$= \mathbf{0.6\ gpm/ft^2}$$

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/ft^2 when the flow is 1,110,000 gpd?

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

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

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

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

PERCENT SOLUTION CALCULATIONS

Determining Percent of Solutions

The strength of a solution is a measure of the amount of chemical solute dissolved in the solution. We use the following equation to determine % strength of solution using the following equation:

$$\% \text{ Strength} = \frac{\text{chemical (lb)}}{\text{Water (lb)} + \text{chemical (lb)}} \times 100$$

Example:

If a total of 10 ounces of dry polymer is added to 15 gallons of water, what is the percent strength (by weight) of the polymer solution?

Before calculating percent strength, the ounces chemical must be converted to lb chemical:

$$\frac{\text{10 ounces}}{\text{16 ounces/pound}} = 0.625 \text{ lb chemical}$$

Now calculate percent strength using:

$$\% \text{ Strength} = \frac{\text{0.625 lb chemical}}{\text{15 gal} \times \text{8.34 lb/gal}} \times 100$$

$$= \frac{\text{0.625 lb chemical}}{\text{125.7 lb solution}} \times 100$$

= 0.5 %

Determining Percent Strength of Liquid Solutions

When using liquid chemicals to make up solutions (e.g., liquid polymer), a different calculation is required, as shown below:

$$\text{Liquid polymer (lb)} \times \frac{\text{liquid polymer (\% strength)}}{100} = \text{poly. Sol. (lb)} \frac{\text{poly. Sol. (\% strength)}}{100}$$

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:

Chemical added (lb/day) = chemical dose (mg/L) x flow (MGD) x 8.34 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:

Chemical (lb/d) = Chemical dose (mg/L) x flow (MGD) x 8.34 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:

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

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

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

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

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:

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

CHEMICAL FEEDER CALBRATIONS

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:

Fed rate (lb/day) = feed rate (lb/min) x 1440 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:

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

Then calculate chemical dosage, lb/day.

Chemical (lb/day) = chemical dose (mg/L) x flow (MGD) x 8.34 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:

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

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

$$\text{Flow rate} = \frac{\text{188 mL/min x 1440 min/day}}{\text{3785 mL/gal}}$$

$$= \text{72 gpd}$$

Then calculate the lb/d polymer feed rate:

Feed rate = 12,000 mg/L x 0.000072 MGD x 8.34 lb/day
= 7.2 lb/day polymer

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.

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

Example:
A filter 18 feet by 22 feet receives a flow of 1750 gpm. What is the filtration rate in gpm/ft^2?

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

$$= \frac{1750 \text{ gpm}}{18 \text{ ft x } 22 \text{ ft}}$$

$$= \mathbf{4.4\ gpm/ft^2}$$

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/ft^2)?

$$\text{Flow rate (gpm)} = \frac{\text{total gallons produced}}{\text{Filter run (min)}}$$

$$= \frac{18{,}000{,}000 \text{ gal}}{76 \text{ hr x } 60 \text{ min/hr}}$$

$$= \mathbf{3947\ gpm}$$

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.

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

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/ft^2)?

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

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

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

Example:
The average filtration rate for a filter was determined to be 2.0 gpm/ft^2. If the filter run time was 4250 minutes, what is the unit filter run volume (gal/ft^2)?

UFRV = 2.0 gpm/ft^2 x 4250 min
= 8500 gal/ft^2

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/ft^2) and areas of the filter (ft^2). The backwash pumping rate can be determined by:

Backwash pumping rate (gpm) = desired backwash rate (gpm/ft^2) x filter area (ft^2)

Example:
A filter is 25 feet long and 20 feet wide. If the desired backwash rate is 22 gpm/ft^2. What is the backwashing pumping rate?

Backwash pumping rate (gpm) = desired backwash rate (gpm/ft^2) x filter area (ft^2)
= 20 gpm/ft^2 x 25 ft x 20 ft
= 10,000 gpm

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?

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

$$= \frac{74{,}000 \text{ gal}}{18{,}100{,}000 \text{ gal}} \times 100$$

= 0.41%

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.

$$\text{dose (mg/L)} = \frac{\text{feed rate (lbs/day)}}{\text{flow (MGD)} \times 8.34 \text{ lb/gal}}$$

$$= \frac{2 \text{ lbs/day}}{1.25 \text{ MGD} \times 8.34 \text{ lb/gal}}$$

$$= 0.19 \text{ mg/L}$$

Actual increase in residual is:

Actual dose (mg/L) = Dose (mg/L) – expected dose (mg/L)
= 0.5 mg/L – 0.19 mg/L
= 0.31 mg/L, YES

LABORATORY CALCULATIONS

Titrations
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 in 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 ($CaCO_3$) equivalent.

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

Example
A 100 mL sample is titrated with 0.02 M H_2SO_4. The endpoint is reached when 6.8 mL of H_2SO_4. The alkalinity concentration is:

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

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

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

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 ($CaCO_3$) 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.

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

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:

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

$$= \frac{\text{7.8 mL x 1,000}}{\text{50 mL}}$$

$$\mathbf{= 156\ mg/L}$$

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.

Potassium Permanganate dose (mg/L) = 1(Iron concentration mg/L) + 2(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.

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

= 1(1.4 mg/L) + 2(1.2 mg/L)
= 3.8 mg/L

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.

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

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.

Weight per gallon = 8.34 lbs/gal x specific gravity

Example
Find the weight per gallon of a liquid that has specific gravity of 1.04.
Weight per gallon = 8.34 lbs/gal x 1.04 = **8.67 lbs/gal**

HORSEPOWER and 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:

$$\text{whp} = \frac{(\text{Flow Rate, gpm})(\text{Total Head, ft})}{3960}$$

Example:
A pump must pump 1500 gallons per minute against a total head of 30 feet. What water horsepower is required to do the work?

Formula:

$$\text{whp} = \frac{(\text{Flow Rate, gpm})(\text{Total Head, ft})}{3960}$$

$$\text{whp} = \frac{(1500 \text{ gpm})(30 \text{ ft})}{3960}$$

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

Note: dividing by 3960 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 1500 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?

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

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

Horsepower requirement = **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 Horsepower = 0.746 kilowatts power

Convert kilowatts to horsepower.

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

Horsepower = 14.75 hp

Calculate the percentage efficiency of the motor.

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

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

Percent efficiency = **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.

Kilowatts = (22 hp)(0.746 kW/hp)
Kilowatts = 16.4 kW

Multiply kilowatts by time.

16.4 Kw X 2 hrs = 32.8 Kw-hrs

Multiply kW-hrs by cost.

32.8 kW-hrs X $0.08 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.

Gpm x 8.34 x Feet of Head = Water Horsepower (WHp)
33,000 ft-lbs/min/Hp

This equation can be further simplified to:
Gpm x Feet of Head = Water Horsepower (WHp)
3960

Brake horsepower is the amount of energy that must go into the pump to produce the required WHp. Loses 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.

BrakeHp = WaterHp

Pump Efficiency

Motor horsepower is the amount of electrical energy that must go into the motor to produce the required BHp. Loses 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

MotorHp = BrakeHp
Motor Eff

OR

MotorHp = WaterHp
Motor Eff x 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.

MotorHp x 0.746 Kw/Hp x Hours = 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 ft + 6 ft = **102 ft**

2. What is the total dynamic head?

    96 ft + 6 ft + 17 ft = **119 ft TDH**

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

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

4. What is the Brake Horsepower?

    Change 80% to a decimal = 0.80
    Find Brake Horsepower

$$\frac{12 \text{ Whp}}{0.80 \text{ Pump Eff}} = \mathbf{15\ BHp}$$

5. What is the Motor Horsepower?

    Change 90% to a decimal = 0.90
    Find Motor Horsepower

$$\frac{15 \text{ BHp}}{0.90 \text{ Motor Eff}} = \mathbf{16.7\ MHp}$$

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

    6.7 MHp x 0.746 Kw/Hp = **12.5 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 Kw x 13 hours/day = 162 Kw-Hours/day

Find cost per day

162 Kw-Hours x $0.09/KwHour = $14.58/day

Find cost for the month

14.58/day x 30 days/month = **$437.40/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 it the total pay that the employee should receive?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CLASS III – EXAM PREPARATION – PRACTICE 1

1. A water system collects 80 bacteriological samples per month. What is the maximum number of positive samples the system can have before they are out of compliance?

2. A clear well at a water plant is 15 feet wide by 25 feet long by 15 feet deep. What is the actual CT value of this tank if the free chlorine is 1.5 mg/L and the peak pumpage into the clear well is 0.3 MGD. Assume a T_{10} value of 10% based on a dye tracer study.

3. A flow of 1.5 MGD is to be treated with a 20% solution of hydrofluosilicic acid. The water to be treated contains no fluoride and the desired fluoride concentration is 0.85 mg/l. Assume the hydrofluosilicic acid weighs 9.8 pounds per gallon. What should the feed rate of hydrofluosilicic acid be in gallons per day?

4. You have a filter that measures 15 feet wide by 35 feet long. The media in the filter is standard filter sand with an anthracite top cap. Your backwash pump has a maximum flow rate of 2,400 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 2,600 gpm. What is your optimum backwash rate in gpm/sq.ft.

5. The optimum level alum dose from jar tests is 18 mg/L. Determine the setting on the liquid alum feeder in gallons per day when the flow is 1.9 MGD. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon solution.

6. A water plant pumps 2.5 MG in a 16 hour day. The raw water has a fluoride level of 0.3 ppm and the operator wants to add enough 20% H_2SiF_6 to raise the fluoride level to 1.0 ppm in the effluent water. Assume a chemical purity of 80% and chemical weighs 10.2 lbs/gal. What would the feed rate be in milliliters per minute?

7. The operator feeds 35% (W/W) liquid caustic soda to adjust the pH of the filtered water. The plant pumps 1.23 MGD and feeds the liquid at a constant rate of 25 ppm. The 35% caustic soda weighs 12 lbs per gallon. How much caustic soda by dry weight is fed in a day?

8. Liquid alum delivered to a water plant contains 446.3 mg/mL of liquid solution. Jar tests indicate the best alum dose is 8 mg/L. Determine the setting on the liquid alum chemical feeder in milliters per minute when the flow is 0.95 MGD.

Use the following information to answer the questions 9-13. 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 x (raw Mn, mg/L)} + raw Fe, mg/L + desired residual
- potassium permanganate in inventory = 17,000 lbs.
- calibration beaker weight = 420 g
- plant flow = 2.75 MGD
- raw water manganese = 2.2 mg/L
- raw water iron = 0.8 mg/L
- chemical supplier does not work on Saturday or Sunday
- a single bulk delivery cannot exceed 38,000 lbs
- desired permanganate residual = 0.1 mg/L
- price for a full bulk delivery = $2,520.00/ton
- time required from order to delivery = 10 working days
- price for deliveries under 12,000 lbs = $3,550.00/ton

Dry Feeder Output per 15 minute grab sample

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

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

10. What is the dry feeder calibration results?

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

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

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

14. A water standpipe with a diameter of 50 feet has an overflow elevation of 778 feet. The elevation at the base is 602 feet. At the foot of the hill is a booster station with a pressure gauge at an elevation of 398 feet. The discharge pressure gauge, with the booster pump off, reads 75 psi. What is the level of water in the tank?

15. What is the turnover percentage in a distribution standpipe that is allowed to draft between 45 and 123 feet in a 24 hour period?

16. A water system bills at a rate of $0.43/1,000 gallons for the first 10,000 gallons; $0.28/1,000 for the next 15,000 gallons; and $0.15/1,000 gallons for all over 25,000 gallons. If a customer uses 43,000 gallons, how much is the water bill?

CLASS III – EXAM PREPARATION – PRACTICE 1 (continued)

17. A plant pumps in June an average of 1.2 MGD. The plant uses 15,000 gallons of potable water (taken from the distribution system) per day to wash filters. The plant meter indicates the plant has used 8,000 gallons per month for in plant water use. If total water sales for the month were 24.56 MG, what is the percentage of lost water for the month?

18. You receive a truckload of NaOCl and the receiving slip states the net weight is 27,338 lbs. The certificate of analysis indicates the specific gravity is 1.21 and the trade % is 16. How many gallons of NaOCl should you receive? If the quoted cost was $0.43/gal., delivered, how much will you pay for the load? If you have two empty 1,600 gallon bulk tanks and a 500 gallon day tank with 175 gallons in it, will you be able to take the entire load?

19. Your treatment plant produces on average 1.95 MGD. You have 8 filters and wash 1 every 96 hours. A filter wash uses 37,000 gallons. If 372,000 gallons of water were used for filter washing in a month that your plant produced 63.7 MG, what percentage of the product water was used for backwashing?

CLASS III – EXAM PREPARATION – PRACTICE 2

1. A water system collects 60 bacteriological samples per month. What is the maximum number of positive samples the system can have before they are out of compliance?

2. A clear well at a water plant is 25 feet wide by 20 feet long by 10 feet deep. What is the actual CT value of this tank if the free chlorine is 2.5 mg/L and the peak pumpage into the clear well is 0.5 MGD. Assume a T_{10} value of 10% based on a dye tracer study.

3. A flow of 2.5 MGD is to be treated with a 20% solution of hydrofluosilicic acid. The water to be treated contains no fluoride and the desired fluoride concentration is 0.95 mg/l. Assume the hydrofluosilicic acid weighs 9.8 pounds per gallon. What should the feed rate of hydrofluosilicic acid be in gallons per day?

4. You have a filter that measures 10 feet wide by 25 feet long. The media in the filter is standard filter sand with an anthracite top cap. Your backwash pump has a maximum flow rate of 2,500 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 2,200 gpm. What is your optimum backwash rate in gpm/sq.ft.

5. The optimum level alum dose from jar tests is 12 mg/L. Determine the setting on the liquid alum feeder in gallons per day when the flow is 1.1 MGD. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon solution.

6. A water plant pumps 3.5 MG in a 16 hour day. The raw water has a fluoride level of 0.2 ppm and the operator wants to add enough 20% H_2SiF_6 to raise the fluoride level to 1.1 ppm in the effluent water. Assume a chemical purity of 80% and chemical weighs 10.2 lbs/gal. What would the feed rate be in milliliters per minute?

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

8. Liquid alum delivered to a water plant contains 579.3 mg/mL of liquid solution. Jar tests indicate the best alum dose is 12 mg/L. Determine the setting on the liquid alum chemical feeder in milliters per minute when the flow is 1.4 MGD.

CLASS III – EXAM PREPARATION – PRACTICE 2 (continued)

Use the following information to answer the questions 9-13. 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 x (raw Mn, mg/L)} + raw Fe, mg/L + 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

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

10. What is the dry feeder calibration results?

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

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

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

14. A water standpipe with a diameter of 50 feet has an overflow elevation of 648 feet. The elevation at the base is 602 feet. At the foot of the hill is a booster station with a pressure gauge at an elevation of 498 feet. The discharge pressure gauge, with the booster pump off, reads 80 psi. What is the level of water in the tank?

15. What is the turnover percentage in a distribution standpipe that is allowed to draft between 35 and 75 feet in a 24 hour period?

16. 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?

17. A plant pumps in June an average of 0.9 MGD. The plant uses 12,000 gallons of potable water (taken from the distribution system) per day to wash filters. The plant meter indicates the plant has used 9,000 gallons per month for in plant water use. If total water sales for the month were 22.22 MG, what is the percentage of lost water for the month?
18. You receive a truckload of NaOCl and the receiving slip states the net weight is 25,798 lbs. The certificate of analysis indicates the specific gravity is 1.18 and the trade % is 16. How many gallons of NaOCl should you receive? If the quoted cost was $0.54/gal., delivered, how much will you pay for the load? If you have two empty 1,200 gallon bulk tanks and a 300 gallon day tank with 150 gallons in it, will you be able to take the entire load?

19. Your treatment plant produces on average 2.75 MGD. You have 8 filters and wash 1 every 96 hours. A filter wash uses 40,000 gallons. If 495,000 gallons of water were used for filter washing in a month that your plant produced 73.2 MG, what percentage of the product water was used for backwashing?

CLASS III/IV – EXAM PREPARTION - PRACTICE IN CLASS

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 x (raw Mn, mg/L)} + raw Fe, mg/L + 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. 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 milliters per minute when the flow is 1.95 MGD.

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 4089 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 1.0 mg/L with a required free chlorine residual 0.6 mg/L and the cost of chlorine is 47 cents per pound.

CLASS IV – EXAM PREPARTION - 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?

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 milliters 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 III/IV – EXAM PREPARTION - PRACTICE HOMEWORK

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 x (raw Mn, mg/L)} + raw Fe, mg/L + 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. Liquid alum delivered to a water plant contains 547.8 mg/mL of liquid solution. Jar tests indicate that the best alum dose is 8 mg/L. Determine the setting on the liquid alum chemical feeder in milliters per minute when the flow is 1.4 MGD.

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.

CLASS IV – EXAM PREPARTION - 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?

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

What is the 90^{th} 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?

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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 = 1,440 minutes	gpd = gallon per day
1 gallon = 8.34 pounds	1 day = 24 hours	MGD = million gallons per day
1 gallon = 3.785 liters	1 lb = 454 grams	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 gpg = 17.12 mg/L	1 gpd = 2.63 mL/min
π(pi) = 3.14	Sp. Gr = specific gravity	Specific gravity (water) = 1.00
W/W = weight/weight	W/V = weight/volume	1 ac-ft = 43,560 cu ft

TEMPERATURE

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

CIRCUMFERENCE, AREA & VOLUME

Circumference (C, ft) = π x diameter (D, ft)

Area of a rectangle (A, sq ft) = (length, ft) x (width, ft)
Area of a circle (A, sq ft) = 0.785 x $(\text{diameter, ft})^2$
Area of a circle (A, sq ft) = π x $(\text{radius, ft})^2$

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

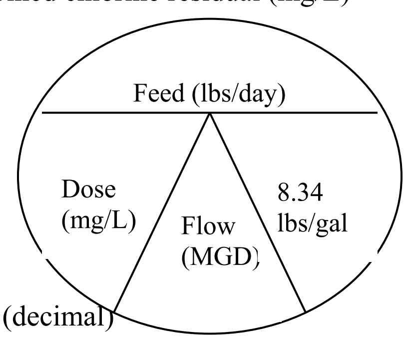
Volume of a cylinder (V, cu ft) = 0.785 x $(\text{diameter, ft})^2$ x (height, ft)
Volume of a cylinder (V, gal) = 0.785 x $(\text{diameter, ft})^2$ x (height, ft) x 7.48 gal/cu ft

CHLORINATION

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

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

POUNDS, DOSAGE & FLOW



Dose (mg/L) = Feed (lbs/day) ÷ flow (MGD) ÷ (8.34 lbs/gal)

Flow (MGD) = Feed (lbs/day) ÷ dose (mg/L) ÷ (8.34 lbs/gal)

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

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

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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

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

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

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

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

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

MISC

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

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

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

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CHEMICAL DOSES

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

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

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

FILTRATION

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

Unit Filter Rate Volume (UFRV) = (Filtration Rate, gpm/sq ft)(Filter Run, hr)(60 min/hr)

Backwash Water, gal = (Backwash Flow, gpm)(Backwash Time, min)

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

CORROSION CONTROL

$pH_s = A + B + \log(Ca^{2+}) + \log(Alk)$

Langlier Index = $pH - pH_s$

COAGULATION AND FLOCCULATION

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

DISINFECTION

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

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

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

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

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

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HORSEPOWER

$$\text{Flow (Q, gpm)} = \frac{(3{,}956) \times \text{HP}}{\text{Head (ft)} \times \text{(Sp.Grav)}}$$

$$\text{Water, HP} = \frac{\text{Flow (Q, gpm)} \times \text{Head (ft)} \times 8.34 \text{ lbs/gal}}{33{,}000 \text{ ft-lbs/min-HP}}$$

kW hour = (HP) x (hours/day) x (0.746 kW/HP)

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

SPECIFIC GRAVITY & DENSITY

$$\text{Density} = \frac{\text{weight of substance}}{\text{volume of substance}}$$

$$\text{Specific gravity} = \frac{\text{density of substance}}{\text{density of water}}$$

$$\text{Specfic gravity} = \frac{\text{weight of substance}}{\text{weight of an equal volume of water}}$$

Weight of substance = Sp. Gr. x weight of water

APPENDIX A - ANSWERS TO: CLASS I EXAM PREPARATION

1. The analytical results of the lead content of your water supply show the following results:

   0.005 mg/L, 0.020 mg/L, 0.018 mg/L, <0.002 mg/L and 0.010 mg/L

   What is the 90^{th} percentile for lead content?

   90^{th} Percentile = 5 x 0.9 = 4.5
   = (#5 + #4)/2
   = (0.020 mg/L + 0.018 mg/L)/2 = [0.038 mg/L]/2 = **0.019 mg/L**

2. What is the average fluoride reading over the past week: 0.91 mg/L, 0.75 mg/L, 0.84 mg/L, 1.22 mg/L, 0.98 mg/L, 1.07 mg/L?

   Average = Sum of Numbers/Total Number

   $$= \frac{0.91 + 0.75 + 0.84 + 1.22 + 0.98 + 1.07 \text{ (mg/L)}}{6}$$

   = [5.77 mg/L]/6 = **0.96 mg/L**

3. A water sample has the following results:
   Bromodichloromethane 0.005 mg/L,
   Chloroform 0.035 mg/L,
   Bromoform 0.002 mg/L,
   Dibromochloromethane 0.006mg/L.

   What is the total of trihalomethanes?

   0.0005 mg/L + 0.035 mg/L + 0.002 mg/L + 0.006 mg/L = **0.048 mg/L**

4. Convert 70°F is what in Celsius?

   °C = 0.56(°F-32) = 0.56(70-32) = 0.56(38) = **21.28°C**

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

   °F = (1.8 x °C) + 32 = (1.8 x 25) + 32 = 45 + 32 = **77°F**

6. In 25 pounds of 70 percent calcium hypochlorite there are how many pounds of available chlorine:

   Chlorine = (Hypochlorite) x (% Purity, as decimal)
   Chlorine = (25 lbs.) x (0.70)
   Chlorine = 17.5 lbs.

7. In water treatment, 17,500 mg/L is considered to be equivalent to:

   17,500 mg/L x (1%/10,000 mg/L) = **1.75%**

8. Convert 6.6 grains per gallon to mg/L of hardness:

   6.6 gpg x [17.12 mg/L]/1 gpg = **112.99 mg/L**

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

   3.25 % x (10,000 mg/L / 1 %) = **32,500 mg/L**

10. What is the chlorine demand if the water has a chlorine dose of 5.2 mg/L and the residual is 0.5 mg/L?

    Demand = Dose – Residual
    = 5.2 mg/L – 0.5 mg/L = **4.7 mg/L**

11. How many pounds of chlorine gas are required to treat 200 gpm of water to provide a 1.8 mg/L residual?

    200 gpm x (1 MGD/694.4 gpm) = 0.288 MGD

    lbs/day = [(dose, mg/L) x (flow, MGD) x 8.34 #/gal]
    = (1.8 mg/L x 0.288 MGD x 8.34 #/gal) = **4.32 lbs**

12. A clearwell is 12 ft deep, 15 ft wide, and 30 feet long. If the flow through the clearwell is 0.25 MGD, what is the detention time in hours?

    V = lwh
    V = (30 ft) x (15 ft) x (12 ft) x (7.48 gal/1 ft^3) = 40,392 gal

    $$V = 40{,}392 \text{ gal} \times \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} = 0.040 \text{ MG}$$

    $$\text{D.T. (days)} = \frac{\text{V (MG)}}{\text{Q (MGD)}} = \frac{0.040 \text{ MG}}{0.25 \text{ MGD}} = 0.16 \text{ days} \times 24 \text{ hr/day} = \mathbf{3.84\ hours}$$

13. A chlorinator is set to feed 40 pounds of chlorine in 24 hours to a flow of 1.05 MGD. Find the chlorine dose in mg/L.

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 #/gal
    = 40 lbs/day ÷ 1.05 MGD ÷ 8.34 #/gal = **4.57 mg/L**

14. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 8-inch diameter water line 12,000 feet long using dosage of 50 mg/L chlorine?

    8 in x 1ft/12 in = 0.67 ft

    Volume = 0.785 x (D, ft)^2 x (L, ft) x 7.48 gal/ft^3
    = 0.785 x 0.67 ft x 0.67 ft x 12,000 ft x 7.48 gal/ft^3
    = 31,630 gal x [1 MG/1,000,000 gal] = 0.032 MGD

    $$\text{lbs} = \frac{(\text{dose, mg/L}) \times (\text{flow, MGD}) \times 8.34\ \#/\text{gal}}{(\%,\ \text{as decimal})}$$

    $$= \frac{50\ \text{mg/L} \times 0.032\ \text{MGD} \times 8.34\ \#/\text{gal}}{0.125} = \frac{13.344\ \text{lbs}}{0.125} = 106.75\text{lbs}$$

    = 106.75 lbs x 1 gal/8.34 lbs = **12.8 gal**

15. The average chlorine residual entering a booster station is 0.8 mg/L. Using a gas chlorine feed system on site, the operator must boost the chlorine to a residual of 2.5 mg/L. The booster pump will run 12 hours per day at a rate 0.25 MGD. How many pounds of Cl_2 will be fed per day?

    Volume Treated = 0.25 MGD x 12 hours x 1 day/24 hours = 0.125 MG
    Dosage Required = 2.5 – 0.8 = 1.7 mg/L
    Amount Cl_2 = 1.7 mg/L x 0.125 MG x 8.34 #/gal = **1.77 lbs**

16. A clearwell is 16 ft deep, 12 ft wide, and 25 feet long. If the flow through the clearwell is 0.50 MGD, what is the detention time in hours?

    V = length, feet x width, feet x height, feet x 7.48 gal/ft^3
    V = 25 ft x 12 ft x 16 ft x 7.48 gal/ft^3 = 35,904 gal
    V = 35,904 gal x (1 MG/1,000,000 gal) = 0.036 MG

    $$\text{D.T. (days)} = \frac{\text{V (MG)}}{\text{Q (MGD)}} = \frac{0.036\ \text{MG}}{0.5\ \text{MGD}} = 0.072\ \text{days} \times 24\ \text{hours/day} = \mathbf{1.73\ hours}$$

17. A water plant uses 15 gallons of sodium fluoride solution in treating 0.35 MGD of water. Natural fluoride ion is 0.15 mg/L. What is the calculated dosage?

    Capacity (gpd) = 0.35 MGD x (1,000,000 gal/1MG) = 350,000 gpd

    $$\text{Dose (mg/L)} = \frac{\text{Solution Fed (gal)} \times 18{,}000\ \text{mg/L}}{\text{Capacity (gpd)}} = \frac{15\ \text{gal} \times 18{,}000\ \text{mg/L}}{350{,}000\ \text{gal}}$$

    $$\text{Dose (mg/L)} = \frac{270{,}000\ \text{mg/L}}{350{,}000} = \mathbf{0.77\ mg/L}$$

APPENDIX A - ANSWERS TO: CLASS I EXAM PREPARATION (CONTINUED):

18. A rectangular reservoir 95 ft x 40 ft x 15 ft is filled with water. How many pounds of chemical must be added in order to produce a dosage of 50 mg/L?

    V = length, feet x width, feet x height, feet x 7.48 gal/ft^3
    V = 95 ft x 40 ft x 15 ft x 7.48 gal/ft^3 = 426,360 gal
    V = 426,360 gal x (1 MG/1,000,000 gal) = 0.43 MG

    Feed = Dose (mg/L) x Flow (MG) x (8.34 lbs/gal)
    Feed = (50 mg/L) x (0.43 MG) x (8.34 lbs/gal)
    Feed = 179.31 lbs

19. What amount of 100% chlorine is required to treat 2.5 million gallons of water to provide a 1 mg/L dose?

    Feed (lbs) = Dose (mg/L) x Flow (MGD) x (8.34 lbs/gal)
    Feed (lbs) = (1 mg/L) x (2.5 MG) x (8.34 lbs/gal) = **20.85 lbs**

20. A container weighing 51 grams is used to calibrate a dry permanganate feeder at a feeder setting of 100%. The container placed under the feeder weighs 105 grams after 2 minutes. What is the dosage in lbs/day?

    $$\text{Chem Feed in g/min} = \frac{105\text{ g} - 51\text{ g}}{2\text{ min}} = \frac{54\text{ g}}{2\text{ min}} = 27\text{ g/min}$$

    Chem feed in grams per day = 27 g/min x 1440 min/1 day= 38,800 g/day

    $$\text{Chem feed in lbs/day} = 38{,}800\text{ g/day} \times \frac{1\text{ lb}}{454\text{ g}} = \mathbf{85.6\text{ lbs/day}}$$

21. Water from a well is being treated by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 10 gpd and uses a 12% available chlorine solution, what is the chlorine dose in mg/L if the well pump delivers 250 gpm?

    Q = 250 gpm x 1 MGD/694.4 gpm = 0.36 MGD

    Pounds = 10 gpd x 8.34 #/gal = 83.4 #/day x 0.12 = 10.008 #/day

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 #/gal
    = 10 lbs/day ÷ 0.36 MGD ÷ 8.34 #/gal = **3.33 mg/L**

22. A chemical pump is calibrated by timing to deliver 560 milliliter in 15 seconds. How much chemical is being added in gallons per minute?

    560 mL/15 sec x 60 sec/1min x 1 L/1000 mL x 1 gal/3.785L = **0.59 gpm**

23. A diaphragm pump feeds a polyphosphate to the clearwell to treat for iron and manganese. At 100% the pump will put out 200 mL per min. The operator must treat a plant flow of 0.50 MGD with 4.5 mg/L of polyphosphate. The polyphosphate weighs approximately 12 lbs/gallon. What is the pump setting?

Feed (lbs) = Dose (mg/L) x Flow (MGD) x (8.34 lbs/gal)
= (4.5 mg/L) x (0.5 MG) x (8.34 lbs/gal) = 18.765 lbs/day

Volume (gal) = 18.765 lbs/day x 1gal/12 lbs = 1.56 gpd
Volume (mL/min) = 1.56 gpd x 1 day/1440 min x 3.785 L/1 gal x 1000 mL/1 L
= 4.11 mL/min

$$\frac{X}{4.11 \text{ mL/min}} = \frac{100\%}{200 \text{ mL/min}}$$

200 mL(X) = (100%)(4.11 mL/min)

$$X = \frac{(100\%)(4.11 \text{ mL/min})}{200 \text{ mL/min}} = \frac{411\ \%}{200} = \mathbf{2.06\%}$$

24. A water treatment plant used 47 chlorine cylinders during one year of operation. The average withdrawal from each cylinder was 146 lbs. What was the total number of pounds of chlorine used for the year?

(47 cylinders/year)(146 lbs/cylinder) = **6,862 lbs/year**

25. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 200,000 gallons of water. The raw water has a natural fluoride content of 0.25 mg/L and the desired fluoride in the finished water is 1.0 mg/L. How many gallons of feed solution is needed?

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

$$\text{Fluoride Feed Rate} = \frac{(0.75 \text{ mg/L})\ (200{,}000 \text{ gallons})}{18{,}000 \text{ mg/L}} = \frac{150{,}000 \text{ gal}}{18{,}000}$$

Fluoride Feed Rate = **8.33 gallons**

APPENDIX A - ANSWERS TO: CLASS I EXAM PREPARATION (CONTINUED):

26. Examination of the raw water shows manganese levels of 0.6 mg/L and total iron levels of 0.3 mg/L. How many pounds of potassium permanganate should be fed to treat 300,000 gallons per day for only iron and manganese?

    Gallons = 300,000 gallons x 1MG/1,000,000 gal = 0.3 MG
    Total $KMnO_4$ Demand = 1 x (Fe conc, mg/L) + 2 x (Mn conc, mg/L)
    = (1 x 0.3 mg/L) + (2 x 0.6 mg/L) = 0.3 mg/L + 1.2 mg/L
    = 1.5 mg/L

    Feed = Dose (mg/L) x Flow (MG) x (8.34 lbs/gal)
    = (1.5 mg/L) x (0.3 MG) x (8.34 lbs/gal) **= 3.753 lbs**

27. The elevation of water in the tank is at 1,450 feet, the elevation of the pump is 520 feet. What is the gauge pressure at the pump?

    520 ft x (1 psi/2.31 ft) = **225.11 psi**

28. Your utility is laying 5,000 feet of 8 inch main to a remote area of your distribution system. Average flow to this area is expected to be 0.02 MGD. What will be the average detention time (in days) for water in 8" main?

    8 inch x 1 ft/12 inch = 0.67 ft

    V = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V = 0.785 x 0.67 ft x 0.67 ft x 5,000 ft x 7.48 gal/ft^3 = 13,179.255 gal
    V = 13,179.255 gal x (1 MG/1,000,000 gal) = 0.013 MG

    $DT = \frac{\text{Volume, MG}}{\text{Flow, MGD}} = \frac{0.013\text{ MG}}{0.02\text{ MGD}} =$ **0.65 days**

29. Find the detention time in hours in a tank that measures 55 ft. long by 35 ft. wide and 20 ft. deep with a flow to the tank of 2,000 gpm.

    Volume = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    = 55 ft x 35 ft x 20 ft x 7.48 gal/ft^3 = 287,980 gal

    $DT = \frac{\text{Volume, gal}}{\text{Flow, gpm}} = \frac{287{,}980\text{ gal}}{2{,}000\text{ gpm}} =$ 143.99 min x 1 hour/60 min = **2.40 hour**

30. If a 100 foot tall tank with a 25 foot diameter contains 68 feet of water, calculate the volume of water in gallons.

    V = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V = 0.785 x 25 ft x 25 ft x 68 ft x 7.48 gal/ft^3 = **249,551.5 gal**

APPENDIX A - ANSWERS TO: CLASS I EXAM PREPARATION (CONTINUED):

31. A distribution booster station operates 12 hours per day. The system requires that the water must be re-chlorinated and expects to use 15 lbs of Cl_2 per day. The booster station pumps 500 gpm. The operator should set the chlorine feed rate at:

    Total lbs / Hours ran = 15 lbs/12 hour = **1.25 lbs per hour**

32. How many hours would it take to use the water in a 75,000 ft. 8 inch pipe with an outflow of 2,000 gpm in an inflow of 500 gpm?

    8 in x (1 ft/12 in) = 0.67 ft

    V = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V = 0.785 x 0.67 ft x 0.67 ft x 75,000 ft x 7.48 gal/ft^3 = 197,688.82 gal

    Flow = 2,000 gpm – 500 gpm = 1,500 gpm

    $$DT = \frac{\text{Volume, gal}}{\text{Flow, gpm}} = \frac{197{,}688.82 \text{ gal}}{1{,}500 \text{ gpm}} = 131.79 \text{ min} \times 1 \text{ hr}/60 \text{ min} = \mathbf{2.20\ hour}$$

33. If chlorine costs \$0.38/lb, what is the daily cost to chlorinate 2.5 MGD of water to an initial concentration of 1.6 mg/L?

    lbs/day = dosage (mg/L) x flow (MGD) x 8.34 lbs/gal
    = 1.6 mg/L x 2.5 MGD x 8.34 lbs/gal = 33.36 lbs/day

    Cost = 33.36 lbs/day x \$0.38/lb = **\$12.68/day**

34. During a 30 day period a booster station pumped 35,250 gallons of water to an isolated pressure zone. During the same period the customers of the zone were billed for a total of 28,300 gallons of water used. Also during this period the high service pumps produced 5,200,000 gallons into the distribution system. What is the water loss percentage for the pressure zone?

    $$\text{Unaccounted} = \frac{(\text{Pumped} - \text{accounted})}{\text{Pumped}} \times 100\% =$$

    $$= \frac{(35{,}250 \text{ gal} - 28{,}300 \text{ gal})}{35{,}250 \text{ gal}} \times 100\% = \frac{6{,}950 \times 100\%}{35{,}250} = \mathbf{19.72\%}$$

APPENDIX A - ANSWERS TO: CLASS I EXAM PREPARATION (CONTINUED):

35. Last month your Water System pumped 5,226,300 gallons of water into the distribution system. Your system was able to account for 2,964,800 gallons. What was your unaccounted for % of water for this month?

$$\text{Unaccounted} = \frac{(\text{Pumped} - \text{accounted})}{\text{Pumped}} \times 100\% =$$

$$= \frac{(5{,}226{,}300 - 2{,}964{,}800)}{5{,}226{,}300} \times 100\% = \frac{2{,}261{,}500 \times 100\%}{5{,}226{,}300} = \mathbf{43.27\%}$$

36. A water system bills at a rate of \$0.55/1,000 gallons for the first 10,000 gallons; \$0.30/1,000 gallons for the next 15,000 gallons; and \$0.15/1,000 gallons for all over 25,000 gallons. If a customer uses 43,000 gallons. How much is the water bill?

43,000 gallons		
-10,000 gallons	x (\$0.55/1000 gallons)	= \$5.50
33,000 gallons		
-15,000 gallons	x (\$0.30/1000 gallons)	= \$4.50
18,000 gallons	x (\$0.15/1000 gallons)	= \$2.70
		\$12.70

37. At the beginning of a day, the master meter reading was 261,289 gallons. The next morning, the master meter reading was 462,006 gallons. The daily flow during the 24-hour period was approximately ___ MGD.

462,006 gal – 261,289 gal = 200,717 gal

200,717 gal x 1 MG/1,000,000 gal = **0.20 MG**

38. Your system is preparing to apply for a rate increase and the PSC is asking about your "unaccounted for water" for the month of July. Your plant produced 1.82 MG in July and the meter readings indicate 1.03 MG was billed. You have been informed that the fire department hauled 75,000 gallons to farmers and the hydrant flushing program used 25,000 gallons. What would you report as the unaccounted for water?

Accounted = 1.03 + 0.075 + 0.025 = 1.13 MG

$$\text{Unaccounted} = \frac{(\text{Pumped} - \text{accounted})}{\text{Pumped}} \times 100\% =$$

$$= \frac{(1.82\text{ MG} - 1.13\text{ MG})}{1.82\text{ MG}} \times 100\% = \frac{0.69\text{ MG}}{1.82\text{ MG}} \times 100\% = \mathbf{37.91\%}$$

APPENDIX B - ANSWERS TO: CLASS II EXAM PREPARATION:

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

   3.25 % x 10,000 mg/L / 1 % = **32,500 mg/L**

2. Convert 20 grains per gallons to mg/L of hardness.

   20 gpg x 17.12 mg/L/1 gpg = **342.2 mg/L**

3. Convert 111 mg/L to grains per gallons.

   121 mg/L x 1 gpg/17.12 mg/L = **7.07 gpg**

4. What is the smallest size pump that is needed to produce twice the daily average of 153,750 gpd?

   2Q = 2 (153,750 gpd) = 307,500 gpd

   2Q = 307,500 gpd x 1 day/1440 min = **213.54 gpm**

5. A ferric chloride pump is calibrated by timing to deliver 870 milliliter in 15 seconds. How much coagulant is being added in gallons per minute?

   $\frac{870 \text{ mL}}{15 \text{ sec}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ gal}}{3.785 \text{ L}} \times \frac{60 \text{ sec}}{1 \text{ min}} =$ **0.92 gpm**

6. The overflow of a water tank is located 145 feet above a neighborhood fire hydrant. Not accounting for c-factor of the pipe, what is the water pressure at the hydrant when the tank is full?

   145 ft x 1 psi/2.31 ft = **62.77 psi**

7. The bottom of a standpipe tank is 1,155 above sea level. The tank has a 30 feet diameter and stands 110feet tall and is 75% full. What is the pressure in pounds per square inch of standing water in the fire hydrant in a valley that has an elevation of 425 feet above sea level?

   h (tank) = 110 ft x 0.75 = 82.5 ft

   Elevation (water level) = Tank Height + Elevation at bottom of tank
   Elevation (water level) = 82.5 ft + 1,155 ft = 1,237.5 ft

   Head (ft) = Elevation (water level) - Elevation (fire hydrant)
   Head (ft) = 1,237.5 ft - 425 ft = 812.5 ft

   Pressure (psi) = 812.5 ft x 1 psi/2.31 ft = **351.73 psi**

8. Convert 27°Celsius to Fahrenheit

   °F = (1.8 x °C) + 32 = (1.8 x 27) + 32 = 48.6 + 32 = **80.6°F**

9. A 100 milliliter sample is titrated with 0.02 M H2SO4. The endpoint is reached when 11.4 milliliters of H_2SO_4 have been added. The alkalinity concentration is:

   $$\text{Alkalinity} = \frac{\text{mL of } H_2SO_4}{\text{mL of sample}} \times 1000$$

   $$= \frac{11.4 \text{ mL}}{100 \text{ mL}} \times 1000 = \mathbf{114 \text{ mg/L}}$$

10. A 50 milliliter sample is titrated with 0.01 M EDTA. The endpoint is reached when 11.4 milliliters of EDTA have been added. The hardness concentration is:

    $$\text{Hardness} = \frac{\text{mL of EDTA}}{\text{mL of sample}} \times 1000$$

    $$= \frac{11.4 \text{ mL}}{50 \text{ mL}} \times 1000 = \mathbf{228 \text{ mg/L}}$$

11. Calculate the 90th percentile for lead using the following data: 0.033 mg/L, 0.011 mg/L, 0.003 mg/L, 0.004 mg/L, 0.023 mg/L.

    90th Percentile = 5 x 0.9 = 4.5
    = (#5 + #4)/2
    = (0.033 mg/L + 0.023 mg/L)/2 = [0.056 mg/L]/2 = **0.028 mg/L**

12. What is the 90th percentile for lead in the following samples: 0.022 mg/L, 0.025 mg/L, 0.015 mg/L, 0.010 mg/L, 0.028 mg/L, 0.021 mg/L, 0.002 mg/L, <0.002 mg/L, <0.002 mg/L and 0.002 mg/L?

    90th Percentile = 10 x 0.9 = 9 (second highest reading) = 0.025 mg/L

13. A water sample has the following results:
    Bromodichloromethane 0.005 mg/L,
    Chloroform 0.035 mg/L,
    Bromoform 0.002 mg/L,
    Dibromochloromethane 0.006mg/L.

    What is the total of trihalomethanes?

    0.0005 mg/L + 0.035 mg/L + 0.002 mg/L + 0.006 mg/L = **0.048 mg/L**

14. A water system analytical results indicates an iron level of 0.3 mg/L and a manganese level of 0.6 mg/L. Determine the estimated demand of potassium permanganate.

    $KMnO_4$ Demand = 1 x (Fe conc, mg/L) + 2 x (Mn conc, mg/L)
    = (1 x 0.3 mg/L) + (2 x 0.6 mg/L) = 0.3 mg/L + 1.2 mg/L
    = 1.5 mg/L

15. What is the minimum amount of water that will be needed to flush an 8 inch main that is 22,000 feet long for 30 minutes prior to disinfection and for 45 minutes after the water in line has been left standing for 6 hours? The water will pump at 750 gpm.

    V = flow, gpm x time, min
    V = 750 gpm x (30 min + 45 min) = 750 gpm x 75 min = **56,250 gal**

16. A water system has 2,500 feet of 8-inch mains, 6,500 feet of 6-inch mains, two storage tanks (50 feet in diameter and 128 feet high), and a 55'x 35'x 20' clearwell. How much water will be in the system when everything is full?

    8 inch x 1 ft/12 inch = 0.67 ft
    6 inch x 1 ft/12 inch = 0.50 ft

    V_1 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_1 = 0.785 x 0.67 ft x 0.67 ft x 5,000 ft x 7.48 gal/ft^3 = 6,589.63 gal

    V_2 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_2 = 0.785 x 0.50 ft x 0.50 ft x 6,500 ft x 7.48 gal/ft^3 = 9,541.68 gal

    V_3 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_3 = 0.785 x 50 ft x 50 ft x 128 ft x 7.48 gal/ft^3 = 1,878,976 gal
    V_3 = 2 (1,878,976 gal)
    V_3 = 3,757,952 gal

    V_4 = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    V_4= 55 ft x 35 ft x 20 ft x 7.48 gal/ft^3 = 287,980 gal

    V = V_1 + V_1 + V_3 + V_4
    V = 6,589.63 gal + 9,541.68 gal + 3,757,952 gal + 287,980 gal = **4,062,063.2 gal**

APPENDIX B - ANSWERS TO: CLASS II EXAM PREPARATION (CONTINUED):

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

    14 inch x 1 ft/12 inch = 1.17 ft
    8 inch x 1 ft/12 inch = 0.67 ft
    6 inch x 1 ft/12 inch = 0.50 ft

    V_1 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_1 = 0.785 x 1.17 ft x 1.17 ft x 17,005 ft x 7.48 gal/ft^3 = 136,684.6 gal

    V_2 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_2 = 0.785 x 0.67 ft x 0.67 ft x 8,523 ft x 7.48 gal/ft^3 = 22,465.36 gal

    V_3 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_3 = 0.785 x 0.50 ft x 0.50 ft x 12,000 ft x 7.48 gal/ft^3 = 17,615.4 gal

    V_4 = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V_4 = 0.785 x 35 ft x 35 ft x 28 ft x 7.48 gal/ft^3 = 201,402.74 gal
    V_4 = 2 (201,402.74 gal)
    V_4 = 402,805.48 gal

    V_4 = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    V_4= 55 ft x 35 ft x 20 ft x 7.48 gal/ft^3 = 287,980 gal

    $V = V_1 + V_1 + V_3 + V_4 + V_5$
    V = 136,684.6 gal + 22,465.36 gal + 17,615.4 gal + 402,805.48 gal + 287,980 gal
    = **867,550.84 gal**

18. What is the minimum amount of water that will be used to disinfect a 8 inch main that is 12,800 feet long to 50 ppm and flush the main?

    8 inch x 1 ft/12 inch = 0.67 ft

    V = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V = 0.785 x 0.67 ft x 0.67 ft x 12,800 ft x 7.48 gal/ft^3 = 33,738.89 gal
    V = 2 (33,738.89 gal)
    V = 67,477.79 gal

APPENDIX B - ANSWERS TO: CLASS II EXAM PREPARATION (CONTINUED):

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

    956,000 gal x 1 MG/1,000,000 gal = 0.956 MGD

    8 gallons x 9.2 lbs/gal. = 73.6 lbs

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

    $$\text{Dose (mg/L)} = \frac{\text{73.6 lbs x 0.28 purity x 0.792 AFI} = \text{16.32 mg/L}}{\text{0.956 MGD x 8.34 lbs/gal} = \text{7.97}} = \mathbf{2.05\ mg/L.}$$

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

    155,000 gal x 1 MG/1,000,000 gal = 0.155 MGD

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

    $$\text{Dose (mg/L)} = \frac{\text{5.3 lbs x 0.453 AFI x 0.98 purity} = \text{2.35 mg/L}}{\text{0.155 MGD x 8.34 lbs/gal} = \text{1.29}} = \mathbf{1.82\ mg/L.}$$

21. The feed solution from your up-flow saturator containing 18,000 mg/L fluoride ion is used to treat a total flow of 150,000 gallons of water. The raw water has a natural fluoride content of 0.45 mg/L and the desired fluoride in the finished water is 1.1 mg/L. How many gallons of feed solution is needed?

    Dose (mg/l) = 1.1 mg/L - 0.45 mg/L = 0.65 mg/L

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

    $$\text{Feed Rate (gpd)} = \frac{\text{0.65 mg/L x 150,000 gpd}}{\text{18,000 mg/L}} = \frac{\text{97,500 gpd}}{\text{18,000 mg/L}} = \mathbf{5.42\ gpd}$$

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

    0.75 MGD x 694.4 gpm/1 MGD = 520.8 gpm

    $$\text{Flow, gpm} = \frac{\text{flow, gpm}}{\text{\# of filters}} = \frac{520.8\text{ gpm}}{2} = 260.4\text{ gpm}$$

    Area, ft^2 = length, feet x width, feet = 10 ft x 10 ft = 100 ft^2

    $$\text{Filtration Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{260.4\text{ gpm}}{100\text{ ft}^2} = \mathbf{2.60\ gpm/ft^2}$$

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

    Area, ft^2 = length, feet x width, feet = 10 ft x 10 ft = 100 ft^2

    Backwash Water, gal = Backwash Flow, gpm/ft^2 x Backwash Time, min x Area, ft^2
    = 22.5 gpm/ft^2 x 15 min x 100 ft^2 = 33,750 gal

    $$\text{Backwash \%} = \frac{\text{V of Backwash}}{\text{V total daily production}} \times 100\%$$

    Backwash % = $\underline{\text{33,750 gal}}$ x 100% = **6.75%**

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

    Area, ft^2 = length, feet x width, feet = 10 ft x 15 ft = 150 ft^2

    Flow, gpm = (6 min. x 1,100 gpm) + (9 min. x 2,200 gpm)
    = 6,600 gal + 19,800 gal = 26,400 gal

    $$\text{Backwash Vol, g/sq ft} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}} = \frac{26{,}400\text{ gal}}{150\text{ ft}^2} = 176\text{ gal/ft}^2$$

    Average flow rate, gpm/ft^2 = [176 gal/ft^2]/15 min = **11.73 gpm/ft²**

25. A filter that had been in service for 2 days, filtered 1.5 MG. If the filter is 12 feet wide by 18 feet in length, what was the average flow rate through the filter in gpm?

    $$\frac{\text{1.5 MG x 1,000,000 gal/MG}}{\text{2 day x 1440 min/day}} = \frac{\text{1,500,000 gal}}{\text{2,880 min}} = \mathbf{520.83\ gpm}$$

APPENDIX B - ANSWERS TO: CLASS II EXAM PREPARATION (CONTINUED):

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

    Area, ft^2 = length, feet x width, feet = 10 ft x 15 ft = 150 ft^2

    Backwash rate, gpm = Backwash rate, gpm/ft^2 x Area, ft^2
    = 20 gpm/ft^2 x 150 ft^2 = **3,000 gpm**

27. What is the dosage (of/where) 9 lbs of chlorine gas is added to 220,000 gallons of finished water?

    220,000 gal x 1 MG/1,000,000 gal = 0.22 MG

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 #/gal
    = 9 lbs/day ÷ 0.22 MGD ÷ 8.34 #/gal = **4.91 mg/L**

28. How many pounds of HTH (65%) are needed to disinfect at 50 ppm a 8-inch diameter line that is 12,000 feet long?

    8 in x 1ft/12 in = 0.67 ft

    Volume = 0.785 x (D, ft)^2 x (L, ft) x 7.48 gal/ft^3
    = 0.785 x 0.67 ft x 0.67 ft x 12,000 ft x 7.48 gal/ft^3 = 31,630.21 gal

    Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal) ÷ % purity (decimal)
    = 50 mg/L x .03 MGD x 8.34 lbs/gal ÷ .65
    = 20.29 lbs/day

29. Determine the setting on a potassium permanganate chemical feed pump in pounds per day if the demand is determined to be 1.6 ppm and a permanganate residual of 0.4 ppm and the flow is 0.45 MGD.

    Dose (mg/L) = Demand, mg/L + Residual, mg/L
    Dose (mg/L) = 1.6 mg/l + 0.4 mg/l
    Dose (mg/L) = 2.0 mg/l

    Feed (lb/day) = Dose, mg/L x flow, MGD x 8.34 lb/gal
    Feed (lb/day) = 2.0 mg/L x 0.45 MGD x 8.34 lb/gal = **7.51 lb/day**

30. How many pounds of 65% HTH are needed to shock a 8 inch diameter pipe that is 12,000 feet long to 50 ppm of chlorine residual?

    8 in x 1ft/12 in = 0.67 ft

    V = 0.785 x diameter, feet x diameter, feet x length, feet x 7.48 gal/ft^3
    V = 0.785 x 0.67 ft x 0.67 ft x 12,000 ft x 7.48 gal/ft^3 = 31,630.21 gal
    = 31,630.21 gal x 1 MG/1,000,000 gal = 0.032 MG

    Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal) ÷ % purity (decimal)
    = 50 mg/L x 0.032 MGD x 8.34 lbs/gal ÷ 0.65 = **20.53 lbs/day**

31. 0.1116 lb/min of soda ash is fed into 1,525,000 gal/day of treated water. What is the soda ash dosage?

    1,525,000 gal/day x 1 MG/1,000,000 gal = 1.525 MGD

    0.1116 lb/min x 1440 min/day = 160.7 lb/day

    Dose (mg/L) = lbs/day ÷ flow, MGD ÷ 8.34 #/gal
    = 160.7 lbs/day ÷ 1.525 MGD ÷ 8.34 #/gal = **12.64 mg/L**

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

    V = L, ft x W, ft x H, ft x 7.48 gal/ft^3
    = 50 ft x 140 ft x 10 ft x 7.48 gal/ft^3 = 523,600 gal
    = 523,600 gal x 1 MG/1,000,000 gal = 0.52 MG

    $$\text{D.T.} = \frac{\text{Vol, MG}}{\text{Flow, MGD}} = \frac{0.52 \text{ MG}}{5.3 \text{ MGD}} = 0.098 \text{ day} \times 24 \text{ hour/day} = \textbf{2.35 hours}$$

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

    Height = 52 ft x 0.8 = 41.6 ft

    35 gpm x 1 MGD/694.4 gpm = 0.05 MGD

    Volume = 0.785 x diameter x diameter x height x 7.48 gal/ft^3
    = 0.785 x 12 ft x 12 ft x 41.6 ft x 7.48 gal/ft^3 = 35,174.43 gal
    = 35,174.43 gal x 1 MG/1,000,000 gal = 0.035 MG

$$\text{D.T.} = \frac{\text{Vol, MG}}{\text{Flow, MGD}} = \frac{0.035 \text{ MG}}{0.05 \text{ MGD}} = 0.7 \text{ day} \times 24 \text{ hour/day} = \textbf{16.9 hours}$$

APPENDIX C - ANSWERS TO: CLASS III – EXAM PREPARATION – PRACTICE 1 – ANSWERS

1. 80 x 0.05 = 4.0 **3 samples**

2. Volume of a rectangle (V, gal) = (length, ft) x (width, ft) x (height, ft) x 7.48 gal/cu ft
   = 15 ft x 25 ft x 15 ft x 7.48 gal/cu ft
   = 42,075 gal

   0.3 MGD x 694.4 gpm/1MGD = 208.32 gpm

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

   $$= \frac{42{,}075 \text{ gal} \times 0.10 \times 1.5 \text{ mg/L}}{208.32 \text{ gpm}} = \frac{6{,}311.25 \text{ mg/L}}{208.32 \text{ min}} = \mathbf{30.30\ mg/L\text{-}min}$$

3. $$\text{Feed Rate, lbs/day} = \frac{(\text{Flow,MGD})(\text{Desired F,mg/l})(8.34\text{lbs/gal})}{(\text{Acid Solution, \%})\ (\text{Purity, \%})}$$

   $$= \frac{(1.5 \text{ MGD})\ (0.85 \text{ mg/l})\ (8.34 \text{ lbs/gal})}{(0.20)\ (0.792)}$$

   = 67.13 lbs Acid/day

   $$\text{Feed Rate, gal/day} = \frac{\text{feed rate lbs/day}}{\text{Acid, lbs/gal}}$$

   $$= \frac{67.13 \text{ lbs Acid/day}}{9.8 \text{ lbs Acid/gal}}$$

   = **6.85 gal Acid/day**

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

   $$= \frac{2{,}600 \text{ gpm}}{(15 \text{ ft} \times 35 \text{ ft})} = \frac{2{,}600 \text{ gpm}}{525 \text{ sqft}} = \mathbf{4.95\ gpm/sqft}$$

5. Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal)
   = 18 mg/L x 1.9 MGD x 8.34 lbs/gal = 285.23 lbs/day

   285.23 lbs/day x 1 gal/5.36 lbs = **53.21 gpd**

6. Dosage Required = 1.0 ppm – 0.3 ppm = 0.7 ppm

   Feed Rate Pounds per Day =
   $$\frac{(\text{Flow,MGD}) \text{X} (8.34 \text{ lbs/gal}) \text{ X} (\text{Dose, mg/L})}{(\text{\% conc., as decimal}) \text{ X } (\text{\% purity, as decimal})}$$

$$= \frac{(2.5 \text{ MGD}) \times (8.34 \text{ lbs/gal}) \times (0.7 \text{ mg/L})}{(0.20 \text{ conc.}) \times (0.80 \text{ Purity})} = \frac{14.60 \text{ lbs/day}}{0.16} = 91.25 \text{ lbs/day}$$

= (91.25 lbs/day) X (1 gal/ 10.2 lbs)

= 8.94 gpd x 3.785 L/gal x 1000 mL/1L = 33,860.91 mL/day

= For 16 hours x 60 min/hr = 960 minutes:

= (33,860.91 mL/day)/960 min = **35.27 mL/min**

7. Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal)
 = 25 mg/L x 1.23 MGD x 8.34 lbs/gal = 256.46 lbs/day
 = 256.46 lbs/day x 0.35 = **89.76 lbs/day**

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

$$= \frac{(0.95 \text{ MGD})(8 \text{ mg/L})(3.785 \text{ L/gal})(1{,}000{,}000 \text{ gal/MG})}{(446.3 \text{ mg/mL})(24 \text{ hr/day})(60 \text{ min/hr})}$$

$$= \frac{28{,}766{,}000 \text{ mL}}{642{,}672\text{min}} = \mathbf{44.76 \text{ mL/min}}$$

Use the following information to answer the questions 9-13. 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 in inventory = 17,000 lbs.
- calibration beaker weight = 420 g
- plant flow = 2.75 MGD
- raw water manganese = 2.2 mg/L
- raw water iron = 0.8 mg/L
- chemical supplier does not work on Saturday or Sunday
- a single bulk delivery cannot exceed 38,000 lbs
- desired permanganate residual = 0.1 mg/L
- price for a full bulk delivery = $2,520.00/ton
- time required from order to delivery = 10 working days
- price for deliveries under 12,000 lbs = $3,550.00/ton

Dry Feeder Output per 15 minute grab sample

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

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

Dose (mg/L) = 2(raw Mn) + raw Fe + desired Residual
Dose (mg/L) = 2(2.2 mg/L) + 0.8 mg/L + 0.1 mg/L
Dose (mg/L) = 4.4 mg/L + 0.8 mg/L + 0.1 mg/L
Dose (mg/L) = 5.3 mg/L

Feed (lb/day) = [Dose (mg/L)] X [Flow (MGD)] X [8.34 lb/gal]
Feed (lb/day) = (5.3 mg/L) X (2.75 MGD) X (8.34 lb/gal)
Feed (lb/day) = **121.56 lb/day**

10. 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

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

$$\frac{50\ \%}{X} = \frac{121\text{ lbs/day}}{121.56\text{ lbs/day}}$$

121 lbs/day (X) = (152 lbs/day) (50%)

$$X = \frac{(121\text{ lbs/day})(50\%)}{121.56\text{ lbs/day}} = \frac{7{,}600\%}{121} = 49.77\%$$

$$\frac{70\ \%}{X} = \frac{175\text{ lbs/day}}{121.56\text{ lbs/day}}$$

175 lbs/day (X) = (121.56 lbs/day) (70%)

$$X = \frac{(121.56\text{ lbs/day})(70\%)}{175\text{ lbs/day}} = \frac{10640\%}{175} = 48.62\%$$

$$\frac{49.77\ \% + 48.62\%}{2} = \frac{98.39\ \%}{2} = \mathbf{49.2\%}$$

APPENDIX C - ANSWERS TO: CLASS III – EXAM PREPARATION – PRACTICE 1 – ANSWERS

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

$\frac{(121.56 \text{ lb})}{(1 \text{ day})}$ (365 days) = 44,369.4 lb

44,369.4 lb – 38,000 lbs/bulk = 6,369.4 lbs/partial load

38,000 lbs x $\frac{1 \text{ ton}}{2000 \text{ lbs}}$ = 19 ton x $\frac{\$2,520}{\text{ton}}$ = \$47,880

6,369.4 lbs x $\frac{1 \text{ ton}}{2000 \text{ lbs}}$ = 3.18 ton x $\frac{\$3,550}{\text{ton}}$ = \$11,305

\$47,880 + \$11,305= **\$59,185.69**

Therefore, the projected cost (to the nearest hundred) would be **\$59,200.**

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

17,000 lb ÷ 121.56 lb/day = 140 days

Takes 10 days to deliver plus 2 days of weekend

Therefore, day to operate before ordering = 140 days – 12 days = **128 days**

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

$\frac{49.2\%}{X} = \frac{2.75 \text{ MGD}}{3.3 \text{ MGD}}$

(2.9 MGD) X = (49.2%) (3.3 MGD)

X = $\frac{(49.2\%)\ (3.3 \text{ MGD})}{(2.9 \text{ MGD})} = \frac{162.36\%}{2.9}$ = **55.99%**

APPENDIX C - ANSWERS TO: CLASS III – EXAM PREPARATION – PRACTICE 1 – ANSWERS

14. A water standpipe with a diameter of 50 feet has an overflow elevation of 778 feet. The elevation at the base is 602 feet. At the foot of the hill is a booster station with a pressure gauge at an elevation of 398 feet. The discharge pressure gauge, with the booster pump off, reads 75 psi. What is the level of water in the tank?

    Pressure, psi = Pressure Head, ft / 2.31

    Pressure Head, ft = (2.31) X (Pressure, psi)

    = (2.31) X (75 psi) = 173.25 feet of head

    (173.25 ft) + (398 ft) = 571.25 feet of head (at the tank)

    (571.25 ft – 602 ft) = **-30.75 ft**

15. What is the turnover percentage in a distribution standpipe that is allowed to draft between 45 and 123 feet in a 24 hour period?

= 78 ft/123 ft x 100% = **63.41%**

16. A water system bills at a rate of $0.43/1,000 gallons for the first 10,000 gallons; $0.28/1,000 for the next 15,000 gallons; and $0.15/1,000 gallons for all over 25,000 gallons. If a customer uses 43,000 gallons, how much is the water bill?

    43,000 gallons
    -10,000 gallons ($0.43/1,000 gal) = $4.30
    33,000 gallons
    -15,000 gallons ($0.28/1,000 gal) = $4.20
    18,000 gallons ($0.15/1,000 gal) = $2.70
    $11.20

17. A plant pumps in June an average of 1.2 MGD. The plant uses 15,000 gallons of potable water (taken from the distribution system) per day to wash filters. The plant meter indicates the plant has used 8,000 gallons per month for in plant water use. If total water sales for the month were 24.56 MG, what is the percentage of lost water for the month?

    Total Monthly pumpage = 1.2 MG X 30 = 36 MG
    Total Monthly Backwash = (15,000 X 30)/1,000,000 gal/MG = 0.45 MG
    Total Plant Use per Month = (8,000 gallons/1,000,000 gal/MG = 0.008 MG

    Total System Delivery for the month = 36 – 0.45 – 0.008 = 35.54 MG

    $$\% \text{ of lost water} = \frac{35.54\text{ MG} - 24.56\text{ MG}}{35.54\text{ MG}} \times 100\% = \frac{10.98}{35.54} \times 100\% = \mathbf{30.89\%}$$

18. You receive a truckload of NaOCl and the receiving slip states the net weight is 27,338 lbs. The certificate of analysis indicates the specific gravity is 1.21 and the trade % is 16. How many gallons of NaOCl should you receive? If the quoted cost was $0.43/gal., delivered, how much will you pay for the load? If you have two empty 1,600 gallon bulk tanks and a 500 gallon day tank with 175 gallons in it, will you be able to take the entire load?

    Sp Gr x Weight of water = 1.21 X 8.34 lbs/gal = 10.09lbs/gal
    27,338 lbs /10.09 lbs/gal= **2,709.42 gal**

    2,709.42 gal X $0.43/gal = **$1,165.05**

    2,709.42 gal – {(2 x 1,600 gal) + (500 gal – 175gal)}=
    = 2,709.42 gal - (3,200 gal + 325 gal) =
    = 2,709.42 gal - 3,525 gal = -815.58 gal; **YES**

19. Your treatment plant produces on average 1.95 MGD. You have 8 filters and wash 1 every 96 hours. A filter wash uses 37,000 gallons. If 372,000 gallons of water were used for filter washing in a month that your plant produced 63.7 MG, what percentage of the product water was used for backwashing?

    $$\frac{\text{Backwash water, gal}}{\text{Water produced, gal}} \times 100\% = \frac{\text{372,000 gallons}}{\text{63,700,000 gal}} \times 100\% = \mathbf{0.58\%}$$

APPENDIX D – ANSWERS TO: CLASS III EXAM PREPARATION-PRACTICE 2

1. A water system collects 60 bacteriological samples per month. What is the maximum number of positive samples the system can have before they are out of compliance?

   60 x 0.05 = 3.0 **2 samples**

2. A clear well at a water plant is 25 feet wide by 20 feet long by 10 feet deep. What is the actual CT value of this tank if the free chlorine is 2.5 mg/L and the peak pumpage into the clear well is 0.5 MGD. Assume a T_{10} value of 10% based on a dye tracer study.

   Volume of a rectangle (V, gal) = (length, ft) x (width, ft) x (height, ft) x 7.48 gal/cu ft
   = 20 ft x 25 ft x 10 ft x 7.48 gal/cu ft
   = 37,400 gal

   0.5 MGD x 694.4 gpm/1MGD = 347.2 gpm

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

   $$= \frac{37{,}400\text{ gal} \times 0.10 \times 2.5\text{ mg/L}}{347.2\text{ gpm}} = \frac{9{,}350\text{ mg/L}}{347.2\text{ min}} = \mathbf{26.93\ mg/L\text{-}min}$$

3. A flow of 2.5 MGD is to be treated with a 20% solution of hydrofluosilicic acid. The water to be treated contains no fluoride and the desired fluoride concentration is 0.95 mg/l. Assume the hydrofluosilicic acid weighs 9.8 pounds per gallon. What should the feed rate of hydrofluosilicic acid be in gallons per day?

   $$\text{Feed Rate, lbs/day} = \frac{(\text{Flow,MGD})(\text{Desired F,mg/l})(8.34\text{lbs/gal})}{(\text{Acid Solution, \%})\ (\text{Purity, \%})}$$

   $$= \frac{(2.5\text{ MGD})\ (0.95\text{ mg/l})\ (8.34\text{ lbs/gal})}{(0.20)\ (0.792)}$$

   $$= 125.05\text{ lbs Acid/day}$$

   $$\text{Feed Rate, gal/day} = \frac{\text{feed rate lbs/day}}{\text{Acid, lbs/gal}}$$

   $$= \frac{125.05\text{ lbs Acid/day}}{9.8\text{ lbs Acid/gal}}$$

   $$= \mathbf{12.76\ gal\ Acid/day}$$

APPENDIX D – ANSWERS TO: CLASS III EXAM PREPARATION--PRACTICE 2 (CONTINUED):

4. You have a filter that measures 10 feet wide by 25 feet long. The media in the filter is standard filter sand with an anthracite top cap. Your backwash pump has a maximum flow rate of 2,500 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 2,200 gpm. What is your optimum backwash rate in gpm/sq.ft.

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

$$= \frac{2{,}200 \text{ gpm}}{(10 \text{ ft} \times 25 \text{ ft})} = \frac{2{,}200 \text{ gpm}}{250 \text{ sqft}} = \mathbf{8.8 \text{ gpm/sqft}}$$

5. The optimum level alum dose from jar tests is 12 mg/L. Determine the setting on the liquid alum feeder in gallons per day when the flow is 1.1 MGD. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon solution.

Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal)
= 12 mg/L x 1.1 MGD x 8.34 lbs/gal = 110.09 lbs/day

110.09 lbs/day x 1 gal/5.36 lbs = **20.54 gpd**

6. A water plant pumps 3.5 MG in a 16 hour day. The raw water has a fluoride level of 0.2 ppm and the operator wants to add enough 20% H_2SiF_6 to raise the fluoride level to 1.1 ppm in the effluent water. Assume a chemical purity of 80% and chemical weighs 10.2 lbs/gal. What would the feed rate be in milliliters per minute?

Dosage Required = 1.1 ppm – 0.2 ppm = 0.9 ppm

Feed Rate Pounds per Day =

$$\frac{\text{(Flow,MGD)X(8.34 lbs/gal)X(Dose, mg/L)}}{\text{(\% conc.) X (\% puritiy)}}$$

$$= \frac{\text{(3.5 MGD) X (8.34 lbs/gal) X (0.9 mg/L)}}{\text{(0.20 conc.) X (0.80 Purity)}} = 164.19 \text{ lbs/day}$$

$$= \frac{\text{(164.19 lbs/day)}}{\text{10.2 gallons}}$$

= 16.1 gpd x 3.785 L/gal x 1000 mL/1L = 60,938.5 mL/day

= For 16 hours x 60 min/hr = 960 minutes:

$$= \frac{\text{(60,927.37 mL/day)}}{\text{960 min}} = \mathbf{63.47 \text{ mL/min}}$$

APPENDIX D – ANSWERS TO: CLASS III EXAM PREPARATION-- PRACTICE 2 (CONTINUED):

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

   Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal)
   = 37 mg/L x 1.5 MGD x 8.34 lbs/gal = 462.87 lbs/day
   = 462.87 lbs/day x 0.25 = **115.72 lbs/day**

8. Liquid alum delivered to a water plant contains 579.3 mg/mL of liquid solution. Jar tests indicate the best alum dose is 12 mg/L. Determine the setting on the liquid alum chemical feeder in milliters per minute when the flow is 1.4 MGD.

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

$$= \frac{\text{(1.4 MGD)(12 mg/L)(3.785 L/gal)(1,000,000 gal/MG)}}{\text{(579.3 mg/mL)(24 hr/day)(60 min/hr)}}$$

$$= \frac{\text{63,588,000 mL}}{\text{834,192 min}} = \textbf{76.23 mL/min}$$

Use the following information to answer the questions 9-13. 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 x (raw Mn, mg/L)} + raw Fe, mg/L + 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

APPENDIX D – ANSWERS TO: CLASS III EXAM PREPARATION--PRACTICE 2 (CONTINUED):

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

Dose (mg/L) = 2(raw Mn) + raw Fe + desired Residual
Dose (mg/L) = 2(2.8 mg/L) + 0.6 mg/L + 0.1 mg/L
Dose (mg/L) = 5.6 mg/L + 0.6 mg/L + 0.1 mg/L
Dose (mg/L) = 6.3 mg/L

Feed (lb/day) = [Dose (mg/L)] X [Flow (MGD)] X [8.34 lb/gal]
Feed (lb/day) = (6.3 mg/L) X (2.9 MGD) X (8.34 lb/gal)
Feed (lb/day) = **152.37 lb/day**

10. What is the dry feeder calibration results?

30 % yields

$$775\text{ g} - 450\text{ g} = 325\text{ g} \times \frac{1\text{ lb}}{454\text{ g}} = \frac{0.72\text{ lbs} \times 60\text{ min} \times 24\text{ hr}}{15\text{ min} \times 1\text{ hr} \times 1\text{ day}} = 68.72\text{ lbs/day}$$

50 % yields

$$992\text{ g} - 450\text{ g} = 542\text{ g} \times \frac{1\text{ lb}}{454\text{ g}} = \frac{1.19\text{ lbs} \times 60\text{ min} \times 24\text{ hr}}{15\text{ min} \times 1\text{ hr} \times 1\text{ day}} = 114.61\text{ lbs/day}$$

70 % yields

$$1248\text{ g} - 450\text{ g} = 798\text{ g} \times \frac{1\text{ lb}}{454\text{ g}} = \frac{1.76\text{ lbs} \times 60\text{ min} \times 24\text{ hr}}{15\text{ min} \times 1\text{ hr} \times 1\text{ day}} = 168.74\text{ lbs/day}$$

$$\frac{50\ \%}{X} = \frac{114.61\text{ lbs/day}}{152\text{ lbs/day}}$$

114.61 lbs/day (X) = (152 lbs/day) (50%)

$$X = \frac{(152\text{ lbs/day})\ (50\%)}{114.61\text{ lbs/day}} = \frac{7{,}600\%}{114.61} = 66.31\%$$

$$\frac{70\ \%}{X} = \frac{168.74\text{ lbs/day}}{152\text{ lbs/day}}$$

168.74 lbs/day (X) = (152 lbs/day) (70%)

$$X = \frac{(152\text{ lbs/day})\ (70\%)}{168.74\text{ lbs/day}} = \frac{10640\%}{168.74} = 63.06\%$$

$$\frac{66.31\% + 63.06\%}{2} = \frac{129.37\%}{2} = \mathbf{64.69\%}$$

APPENDIX D – ANSWERS TO: CLASS III EXAM PREPARATION--PRACTICE 2 (CONTINUED):

11. 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 lb – 48,000 lbs/bulk = 7,615 lbs/partial load

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

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

$84,480 + $12,374 = **$96,854**

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

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

15,000 lb ÷ 152.37 lb/day = 98.4 days

Takes 10 days to deliver plus 2 days of weekend

Therefore, day to operate before ordering = 98.4 days – 12 days = **86.4 days**

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

$$\frac{X\,\%}{64.69\%} = \frac{3.3 \text{ MGD}}{2.9 \text{ MGD}}$$

$$(2.9 \text{ MGD})\, X = (64.69\%)\,(3.3 \text{ MGD})$$

$$X = \frac{(64.69\%)\,(3.3 \text{ MGD})}{(2.9 \text{ MGD})} = \frac{213.48\%}{2.9} = \mathbf{73.61\%}$$

APPENDIX D – ANSWERS TO: CLASS III EXAM PREPARATION--PRACTICE 2 (CONTINUED):

14. A water standpipe with a diameter of 50 feet has an overflow elevation of 648 feet. The elevation at the base is 602 feet. At the foot of the hill is a booster station with a pressure gauge at an elevation of 498 feet. The discharge pressure gauge, with the booster pump off, reads 80 psi. What is the level of water in the tank?

    Pressure, psi = Pressure Head, ft / 2.31

    Pressure Head, ft = (2.31) X (Pressure, psi)

    = (2.31) X (80 psi) = 184.8 feet of head

    (184.8 ft) + (498 ft) = 682.8 feet of head (at the tank)

    (682.8 ft – 602 ft) = **80.8 ft**

15. What is the turnover percentage in a distribution standpipe that is allowed to draft between 35 and 75 feet in a 24 hour period?

    = 40 ft/75 ft x 100% = **53.33%**

16. 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?

    35,000 gallons
    -10,000 gallons ($0.35/1,000 gal) = $3.50
    25,000 gallons
    -15,000 gallons ($0.25/1,000 gal) = $3.75
    10,000 gallons ($0.20/1,000 gal) = $2.00
    $9.25

17. A plant pumps in June an average of 0.9 MGD. The plant uses 12,000 gallons of potable water (taken from the distribution system) per day to wash filters. The plant meter indicates the plant has used 9,000 gallons per month for in plant water use. If total water sales for the month were 22.22 MG, what is the percentage of lost water for the month?

    Total Monthly pumpage = 0.9 MG X 30 = 27 MG
    Total Monthly Backwash = (12,000 X 30)/1,000,000 gal/MG = 0.36 MG
    Total Plant Use per Month = (9,000 gallons/1,000,000 gal/MG = 0.009 MG

    Total System Delivery for the month = 27 – 0.36 – 0.009 = 26.63 MG

    $$\% \text{ of lost water} = \frac{26.63 \text{ MG} - 22.22 \text{ MG}}{26.63 \text{ MG}} \times 100\% = \frac{4.41}{26.63} \times 100\% = \mathbf{16.56\%}$$

APPENDIX D – ANSWERS TO: CLASS III EXAM PREPARATION--PRACTICE 2 (CONTINUED):

18. You receive a truckload of NaOCl and the receiving slip states the net weight is 25,798 lbs. The certificate of analysis indicates the specific gravity is 1.18 and the trade % is 16. How many gallons of NaOCl should you receive? If the quoted cost was $0.54/gal., delivered, how much will you pay for the load? If you have two empty 1,200 gallon bulk tanks and a 300 gallon day tank with 150 gallons in it, will you be able to take the entire load?

    Sp Gr x Weight of water = 1.18 X 8.34 lbs/gal = 9.84 lbs/gal
    25,798 lbs /9.84 lbs/gal= **2,621.75 gal**

    2,621.75 gal X $0.54/gal = **$1,415.75**

    2,621.75 gal – {(2 x 1,200 gal) + (300 gal – 150gal)}=
    = 2,621.75 gal - (2,400 gal + 150 gal) =
    = 2,621.75 gal - 2,550 gal = 71.75 gal; **NO**

19. Your treatment plant produces on average 2.75 MGD. You have 8 filters and wash 1 every 96 hours. A filter wash uses 40,000 gallons. If 495,000 gallons of water were used for filter washing in a month that your plant produced 73.2 MG, what percentage of the product water was used for backwashing?

    $$\frac{\text{Backwash water, gal}}{\text{Water produced, gal}} \times 100\% = \frac{495{,}000 \text{ gallons}}{73{,}200{,}000 \text{ gal}} \times 100\% = \mathbf{0.68\%}$$

APPENDIX E - ANSWERS TO: CLASS IV – EXAM PREPARTION - PRACTICE 1 – ANSWERS

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 x (raw Mn, mg/L)} + raw Fe, mg/L + 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

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

Dose (mg/L) = 2(raw Mn) + raw Fe + desired Residual
Dose (mg/L) = 2(2.8 mg/L) + 0.6 mg/L + 0.1 mg/L
Dose (mg/L) = 5.6 mg/L + 0.6 mg/L + 0.1 mg/L
Dose (mg/L) = 6.3 mg/L

Feed (lb/day) = [Dose (mg/L)] X [Flow (MGD)] X [8.34 lb/gal]
Feed (lb/day) = (6.3 mg/L) X (2.9 MGD) X (8.34 lb/gal)
Feed (lb/day) = **152.37 lb/day**

APPENDIX E - ANSWERS TO: CLASS IV – – EXAM PREPARTION - PRACTICE 1 – ANSWERS (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 lbs/day (X) = (152 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 lbs/day (X) = (152 lbs/day) (70%)

$$X = \frac{(152\text{ lbs/day})\ (70\%)}{175\text{ lbs/day}} = \frac{10640\%}{175} = 60.8\%$$

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

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 days) = 55,615.05 lb

   55,615 lb – 48,000 lbs/bulk = 7,615 lbs/partial load

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

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

   $84,480 + $12,374 = **$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 lb ÷ 152.37 lb/day = 98.4 days

   Takes 10 days to deliver plus 2 days of weekend

   Therefore, day to operate before ordering = 98.4 days – 12 days = **86.4 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 MGD) X = (61.8%) (3.3 MGD)

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

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.

   Dose (mg/L) = Demand (mg/L) + Residual (mg/L)
   Dose (mg/L) = 1.0 mg/L + 0.6 mg/L
   Dose (mg/L) = 1.6 mg/L

   Head (ft) = 4356 ft – 4089 ft = 267 ft

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

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

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

   Q (MGD) = 3.20 MGD

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

   (100%)(X) = (3.20 MGD)(72%)

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

   Feed (lb/day) = [Dose (mg/L)] X [Flow (MGD)] X [8.34 lb/gal]
   Feed (lb/day) = (1.6 mg/L) X (2.3 MGD) X (8.34 lb/gal)
   Feed (lb/day) = 30.75 lb/day

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

Cost = (11,334 lb/year) ($0.47/lb) = $5,326.98/ year

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

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?

Feed (lb/day) = [Dose (mg/L)] X [Flow (MGD)] X [8.34 lb/gal]
Feed (lb/day) = (0.8 mg/L) X (0.5 MGD) X (8.34 lb/gal)
Feed (lb/day) = 3.336 lb/day

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

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

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

35 L/min (X) = (100%)(2.19 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 %.**

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 %?

   Dose (mg/L) = Demand (mg/L) + Residual (mg/L)
   Dose (mg/L) = 4.2 mg/L + 1.5 mg/L
   Dose (mg/L) = 5.7 mg/L

   Feed (lb/day) = Dose (mg/L) X Flow (MGD) X (8.34 lb/gal)
   Feed (lb/day) = (5.7 mg/L) X (2.08 MGD) X (8.34 lb/gal)
   Feed (lb/day) = 98.88 lb/day

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

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

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

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

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

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

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

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

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

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.

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

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

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 milliters per minute when the flow is 1.95 MGD.

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

$$= \frac{(1.95\ MGD)(5\ mg/L)(3.785\ L/gal)(1{,}000{,}000\ gal/MG)}{(547.8\ mg/mL)(24\ hr/day)(60\ min/hr)}$$

$$= \frac{36{,}903{,}750\ mL}{788{,}400\ min} = \mathbf{46.81\ mL/min}$$

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?

$$V_1 = 0.785d^2h \times (7.48\ gal/ft^3)$$
$$V_1 = (0.785) \times (12\ ft) \times (12\ ft) \times (14\ ft) \times (7.48\ gal/ft^3)$$
$$V_1 = 11{,}837.55\ gal$$

$$V_2 = 0.785d^2h \times (7.48\ gal/ft^3)$$
$$V_2 = (0.785) \times (35\ ft) \times (35\ ft) \times (10\ ft) \times (7.48\ gal/ft^3)$$
$$V_2 = 71{,}929.55\ gal$$

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

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

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?

90th Percentile = (30 samples) X (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 – EXAM PREPARTION - PRACTICE 2 – ANSWERS

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 x (raw Mn, mg/L)} + raw Fe, mg/L + 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(raw Mn) + raw Fe + desired Residual
   Dose (mg/L) = 2(1.6 mg/L) + 0.6 mg/L + 0.1 mg/L
   Dose (mg/L) = 3.2 mg/L + 0.6 mg/L + 0.1 mg/L
   Dose (mg/L) = 3.9 mg/L

   Feed (lb/day) = [Dose (mg/L)] X [Q (MGD)] X [8.34 lb/gal]
   Feed (lb/day) = (3.9 mg/L) (3.9 MGD) (8.34 lb/gal)
   Feed (lb/day) = **126.85 lb/day**

APPENDIX F- ANSWERS TO: CLASS IV – EXAM PREPARTION - PRACTICE 2 – ANSWERS (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

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

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

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

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

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

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

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

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

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

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

46,300 – 35,000 lbs per bulk = 11,300 lbs per partial load

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

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

\$56,350 + \$16,950 = **\$73,300/12 months**

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

21,000 lb ÷ 126.85 lb/day = 165.5 days

Takes 10 days to deliver plus 2 days of weekend

Therefore, day to operate before ordering = 165 days – 12 days = **153 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 MGD) X = (53.9%) (2.9 MGD)

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

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.

Dose (mg/L) = Demand (mg/L) + Residual (mg/L)
Dose (mg/L) = 1.3 mg/L + 0.6 mg/L
Dose (mg/L) = 1.9 mg/L

Head (ft) = 4356 ft – 4118 ft = 238 ft

HP = 125 HP x 0.82 efficiency = 102.5 HP

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

$$Q\ (\text{gpm}) = \frac{(3956)\ (102.5)}{(238\ \text{ft})\ (1)} = \frac{405{,}490\ \text{gpm}}{238} = 1{,}703.74\ \text{gpm}$$

$$Q\ (\text{MGD}) = 1{,}703.74\ \text{gpm} \times \frac{(1\ \text{MG})}{694.4\ \text{gpm}}$$

Q (MGD) = 2.45 MGD

Feed (lb/day) = Dose (mg/L) X Flow (MGD) X (8.34 lb/gal)
Feed (lb/day) = (1.9 mg/L) X (2.45 MGD) X (8.34 lb/gal)
Feed (lb/day) = 38.82 lb/day

$$\text{Feed (lb/year)} = \frac{(38.82\ \text{lb}) \times (365\ \text{days})}{(1\ \text{day}) \times (1\ \text{year})}$$

Feed (lb/year) = 14,169.3 lb/year

Cost = (14,169.3 lb/year) X ($0.43/lb) = $6,092.80/ year

Therefore, the closest choice within $100 is **$6,100**

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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?

Feed (lb/day) = Dose (mg/L) X flow (MGD) X (8.34 lb/gal)
Feed (lb/day) = (0.75 mg/L) X (0.45 MGD) X (8.34 lb/gal)
Feed (lb/day) = 2.81 lb/day

$$\frac{(2.81\text{ lb})}{(1\text{ day})} \times \frac{(500\text{ gal})}{(2.5\text{ lbs})} = \frac{2.81\text{ lbs X }500\text{ gal}}{2.5\text{ day}} = \frac{1{,}405\text{ gal}}{2.5\text{ day}} = 562\text{ gal/day}$$

$$\frac{(562\text{ gal})\ (3.785\text{ L})\ \ (1\text{ day})}{(1\text{ day})\ \ (1\text{ gal})\ \ (1440\text{ min})} = \frac{2{,}127.17\text{ L}}{1440\text{ min}} = \mathbf{1.47\text{ L/min}}$$

$$\frac{X}{100\ \%} = \frac{1.47\text{ L/min}}{25\text{ L/min}}$$

25 L/min (X) = (100%)(1.47 L/min)

$$X = \frac{(100\%)(1.47)}{25} = \frac{147\%}{25} = \mathbf{5.88\%}$$

Therefore, the pump setting should be **1.47 L/min at 5.88%.**

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 %?

   Dose (mg/L) = Demand (mg/L) + Residual (mg/L)
   Dose (mg/L) = 3.2 mg/L + 1.4 mg/L
   Dose (mg/L) = 4.6 mg/L

   Feed (lb/day) = Dose (mg/L) X Flow (MGD) X (8.34 lb/gal)
   Feed (lb/day) = (4.6 mg/L) X (1.48 MGD) X (8.34 lb/gal)
   Feed (lb/day) = 56.78 lb/day

   $$\frac{X}{1.25\text{ lbs}} = \frac{14.4\%}{15\%}$$

   15%(X) = (1.25 lbs)(14.4%)

   $$X = \frac{(1.25\text{ lbs})(14.4\%)}{15\%} = \frac{18\text{ lbs}}{15} = 1.2\text{ lbs}$$

   $$\frac{56.78\text{ lb/day}}{\text{day}} \text{ X } \frac{1\text{gal}}{1.2\text{ lbs}} = 47.3\text{ gal/day}$$

   $$\frac{(47.3\text{ lb})}{(1\text{ day})} \text{ X } \frac{(1\text{ day})}{(1440\text{ min})} = 0.033\text{ gpm}$$

   $$\frac{X}{100\%} = \frac{0.033\text{ gpm}}{1.9\text{ gpm}}$$

   1.9 gpm(X) = (0.033 gpm) (100 %)

   $$X = \frac{(0.033\text{ gpm})(100\ \%)}{(1.9\text{ gpm})} = \frac{3.3\%}{1.9} = \mathbf{1.74\%}$$

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.

$V\ (gal) = l\ (ft) \times w\ (ft) \times h\ (ft) \times (7.48\ gal/ft^3)$
$V\ (gal) = (42\ ft) \times (45\ ft) \times (11\ ft) \times (7.48\ gal/ft^3)$
$V\ (gal) = (155{,}509\ gal)\ \frac{(1MG)}{(1{,}000{,}000\ gal)} = 0.156\ MGD$

$$D.T. = \frac{Vol\ (MG)}{Flow\ (MGD)} = \frac{(0.156\ MG)}{(1.97\ MGD)}\frac{(1440\ min)}{(1\ day)} = \frac{224.64\ min}{1.97} = \mathbf{114\ min}$$

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 milliters per minute when the flow is 1.23 MGD.

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

$$= \frac{(1.23\ MGD)(7\ mg/L)(3.785\ L/gal)(1{,}000{,}000\ gal/MG)}{(357.8\ mg/mL)(24\ hr/day)(60\ min/hr)}$$

$$= \frac{32{,}588{,}850\ mL}{515{,}232\ min} = \mathbf{63.25\ mL/min}$$

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?

$V_1 = 0.785d^2h \cdot (7.48\ gal/ft^3)$
$V_1 = (0.785) \times (15\ ft) \times (15\ ft) \times (16\ ft) \times (7.48\ gal/ft^3)$
$V_1 = 21{,}138.48\ gal$

$V_2 = 0.785d^2h \cdot (7.48\ gal/ft^3)$
$V_2 = (0.785) \times (15\ ft) \times (15\ ft) \times (19\ ft) \times (7.48\ gal/ft^3)$
$V_2 = 25{,}101.95\ gal$

$V = V_1 + V_2$
$V = 21{,}138.48\ gal + 25{,}101.95\ gal$
$V = 46{,}240.43\ gal \times \frac{1\ MG}{1{,}000{,}000\ gal} = 0.046\ MG$

$$Flow\ (MGD) = \frac{Vol\ (MG)}{DT\ (day)} = \frac{(0.046\ MG)}{(30\ min)}\frac{(1440\ min)}{(1\ day)} = \frac{66.24\ MG)}{30\ day} = \mathbf{2.21\ MGD}$$

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

What is the 90th percentile of the lead level?

90th Percentile = (50 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?

$$\frac{(456\text{ mL})(60\text{ sec})(1\text{ L})(1\text{ gallon})}{(25\text{ sec})(1\text{ min})(1000\text{mL})(3.785\text{L})} = \frac{27{,}360\text{ gal}}{94{,}625\text{ min}} = \mathbf{0.29\ gpm}$$