BASIC WATER MATH FOR UTILITY OPERATOR CERTIFICATION

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Smart Management for
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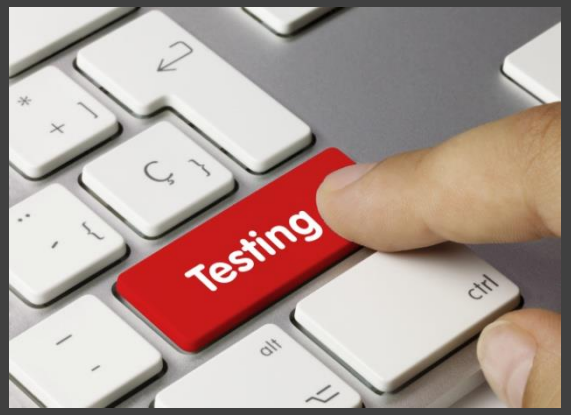
Why Care About Water Math?

Water Operator Certification

: WATER MATH



- Part of the water utility operator certification exam
- Level of math varies with type of exam and level of certification:
  - ❖ Lower levels – may require less math
  - ❖ Exam type e.g. water treatment exam – more advanced math

Tips for solving math problems

- Draw sketches – visualize the problem
- Familiarize yourself with the formula sheet before the exam
- Pay attention to the units
- Practice! Practice! Practice!

Water Math – Terms, Definitions & Measurements

Familiarize yourself with:

- Square feet = (ft^2)
- Cubic feet = (ft^3)
- Cubic ft per sec = ft^3/s or CFS
- Acre feet = (aft)
- Gallons per acre foot = gal/ac ft
- Inches per foot = in/ft
- Mile = mi
- Feet per mile = ft/mi

Water Math – Terms, Definitions & Measurements

Familiarize yourself with:

- Gallons per cubic ft = gal/cu ft
- Pounds per gallon = lbs/gal
- Pounds per square inch = psi
- Gallons per day = gpd
- Gallons per minute = gpm
- Million Gallons = MG
- Million Gallons per day = MGD

Water Math

Formula Sheets

- Most programs allow formula sheets during testing

Example

ABC & C_2EP Formula/Conversion Table for Water Treatment, Distribution, & Laboratory Exams

$$\text{Alkalinity, as mg } CaCO_3/L = \frac{(\text{Titrant Volume, mL})(\text{Acid Normality})(50{,}000)}{\text{Sample Volume, mL}}$$

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{*Area of Circle} = (.785)(\text{Diameter}^2) = (\pi)(\text{Radius}^2)$$

$$\text{Area of Cone (lateral area)} = (\pi)(\text{Radius})\sqrt{\text{Radius}^2 + \text{Height}^2}$$

$$\text{Area of Cone (total surface area)} = (\pi)(\text{Radius})(\text{Radius} + \sqrt{\text{Radius}^2 + \text{Height}^2})$$

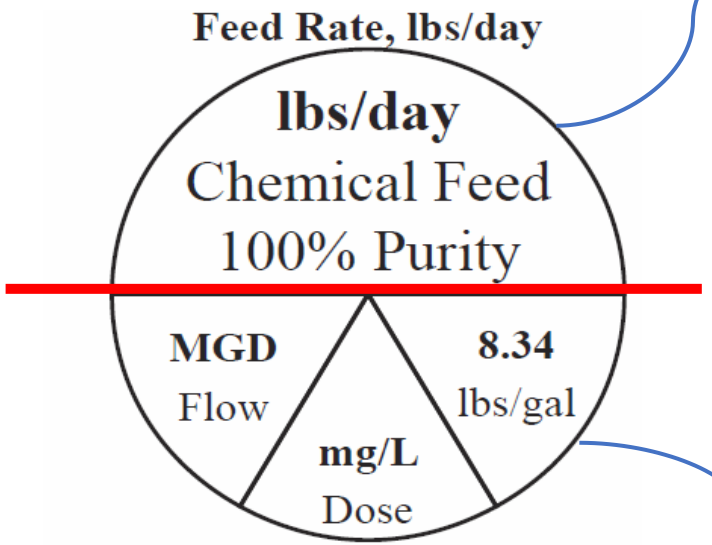
$$\text{Area of Cylinder (total exterior surface area)} = [\text{Surface Area of End \#1}] + [\text{Surface Area of End \#2}] + [(\pi)(\text{Diameter})(\text{Height or Depth})]$$

$$\text{*Area of Rectangle} = (\text{Length})(\text{Width})$$

$$\text{*Area of a Right Triangle} = \frac{(\text{Base})(\text{Height})}{2}$$

Formula Sheet

a) Pie Wheels



Top half: One side of the equation

The top half balances the bottom half of the wheel

Bottom half: Opposite side of the equation

b) Equation

Feed Rate (lbs/d) = Flow (MGD) x Dose (mg/L) x 8.34 lbs/gal

Your units must match the units in the pie wheel

Quick Tip:
Avoid making common mistakes with your units

10 ft, 6 inches $\neq$ **10.6 ft**

= 10.5 ft

$\frac{\text{6 inches}}{\text{12 in/ft}} = 0.5\text{ft}$

5 ft, 9 inches $\neq$ **5.9 ft**

= 5.75 ft

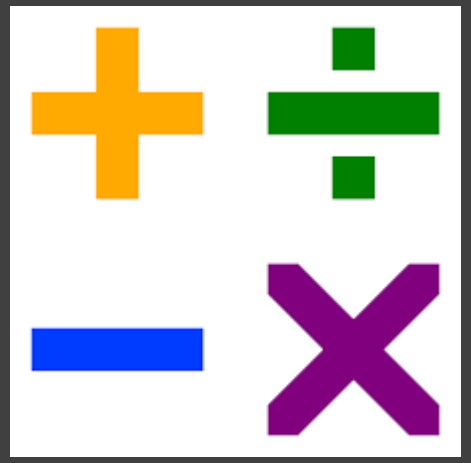
$\frac{\text{9 inches}}{\text{12 in/ft}} = 0.75\text{ft}$

Water Math

Topics To Cover

- Averages
- Fractions and Percents
- Area
- Volume
- Conversions
- Water Pressure Head
- Flow and Velocity
- Dosage Calculations

WATER MATH



Basic Math Concepts

Concept	Definition/Keywords	Example
Exponents	**A number that is multiplied by itself, a specified number of times** • **The power of a number**	Exponent $3^2 = 3 \times 3 = 9$ Base 2 threes
Square Roots	**A number that gives the original value when multiplied by itself.** • **Opposite of an exponent**	$\sqrt{4} = 2$ (2 x 2 = 4)
Averages (Mean)	• **All values in a set are added together (summed up)** • **The sum is divided by the number of values in the set**	1, 2, 3, 6 $1 + 2 + 3 + 6 = 12$ $12 \div 4 = \boxed{3}$

Averages

Q: On Monday at 8:00 am the reading on the master meter was 1,523,951 gals. On Thursday at 8:00 am the meter read 2,859,230 gals. What was the average daily consumption during this time?

What do we have?

Gallons pumped

2,859,230 – 1,523,951 = 1,335,279 gallons

Time Elapsed = 3 days

Avg Daily Consumption = $\frac{\text{Gallons pumped}}{\text{Days elapsed}}$

$$\frac{1{,}335{,}279 \text{ gals}}{3 \text{ days}} = 445{,}093 \text{ gpd}$$

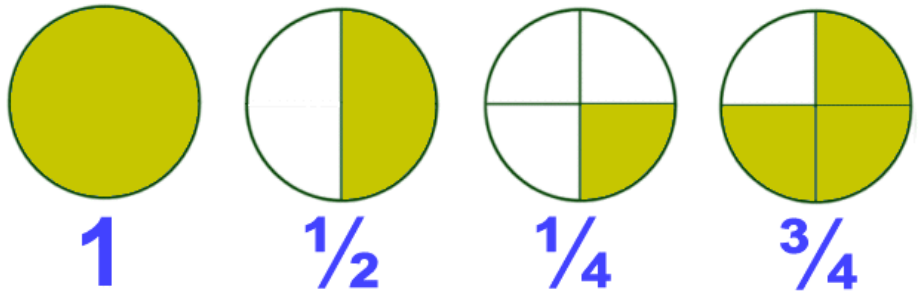
Rounding down….

Answer
445,000 gpd

WATER MATH

Fractions

- Part of a whole number
- Top number = Numerator
- Bottom number = Denominator



Note: All whole numbers have a denominator of ‘1’, that is not always written out e.g. 5 = 5/1

WATER MATH

Percents

- Percents are fractions where the denominator (bottom) is equal to 100

- Applied to water math in different areas e.g. hypochlorite solutions
  - 65%, 12.5% or 100%

- Percents can be converted into fractions and vice versa

Numerator
Denominator

$$\frac{1}{100} = 1\%$$

WATER MATH

Percents and Decimals

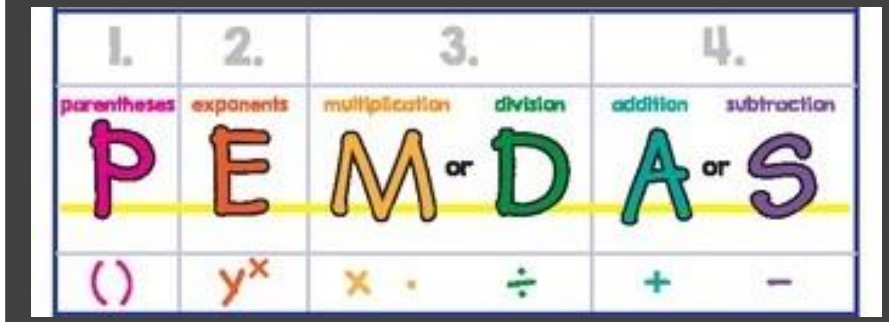
- To change a percent into a decimal: drop the % and divide the number by 100 :

65% = 65/100 = 0.65

- To change a decimal to a percent: multiply the decimal by 100 and add a %

0.12 x 100 = 12%

WATER MATH



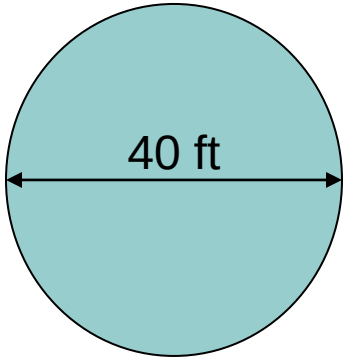
ORDER OF OPERATIONS

A rule that tells you the sequence to follow when solving math problems

- Please (Parentheses)
- Excuse (Exponents)
- My Dear (Multiply or Divide)
- Aunt Sally (Add or Subtract)

Formulas:
$A = \pi r^2$ or
$A = 0.785d^2$

Q: Calculate the Area of a Circle



What do we have?
π = 3.14
Diameter = 40 ft
Radius = D/2 = 20 ft

Formula 1:

$A = \pi \times r^2$

$A = 3.14 \times (20ft)^2$

$A = 3.14 \times (20ft \times 20ft)$

$A = 3.14 \times 400ft^2$

Area = 1256 ft^2

Formula 2:

$A = 0.785 \times d^2$

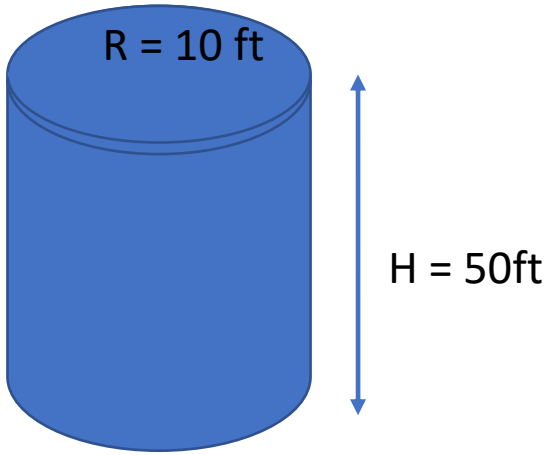
$A = 0.785 \times (40ft \times 40ft)$

$A = 0.785 \times 1600ft^2$

Area = 1256 ft^2

P
E
M
D
A
S

Volumes - Cylinders



Applications

- Storage tanks & reservoirs
- Pipes
- Wells (bore hole)

Tanks

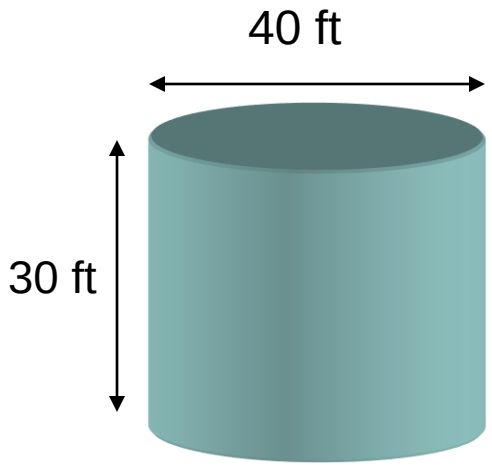
Water Pipes

Wells

(Part A)

$V = \pi r^2 h$
$A = \pi dh$

Q: Calculate the Volume in ft^3 and in gallons:



What do we have?
π = 3.14
Diameter = 40 ft
Radius = D/2 = 20 ft
Height = 30 ft

$V = \pi r^2 h$

$V = 3.14 \times (20ft)^2 \times 30ft$

$V = 3.14 \times (20ft \times 20ft) \times 30ft$

$V = 3.14 \times 400ft^2 \times 30ft$

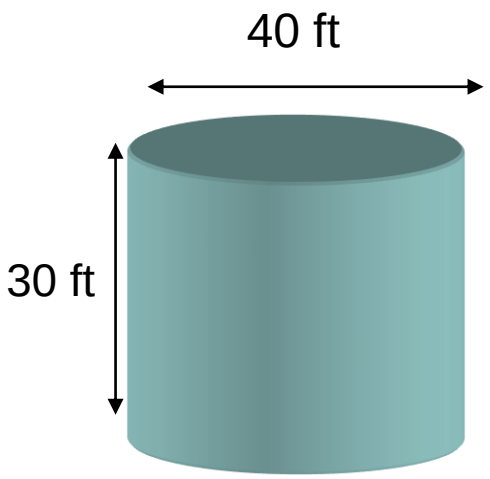
$V = 37{,}680\ ft^3$

Remember to multiply the units too : $ft^2 \times ft = ft^3$)

P E M D A S

(Part B)

Q: Calculate the Volume in gallons:



Convert ft^3 to gallons

V = 37,680 ft^3

Conversion Factor:
1 ft^3 = 7.48 gallons

Quick Tip: There is always more gallons than ft^3

1 ft^3 = 7.48 gallons
37,680 ft^3 = ?

$$= \frac{37{,}680\ ft^3 \times 7.48\ \text{gallons}}{1\ ft^3}$$

= 281, 846.4 gallons

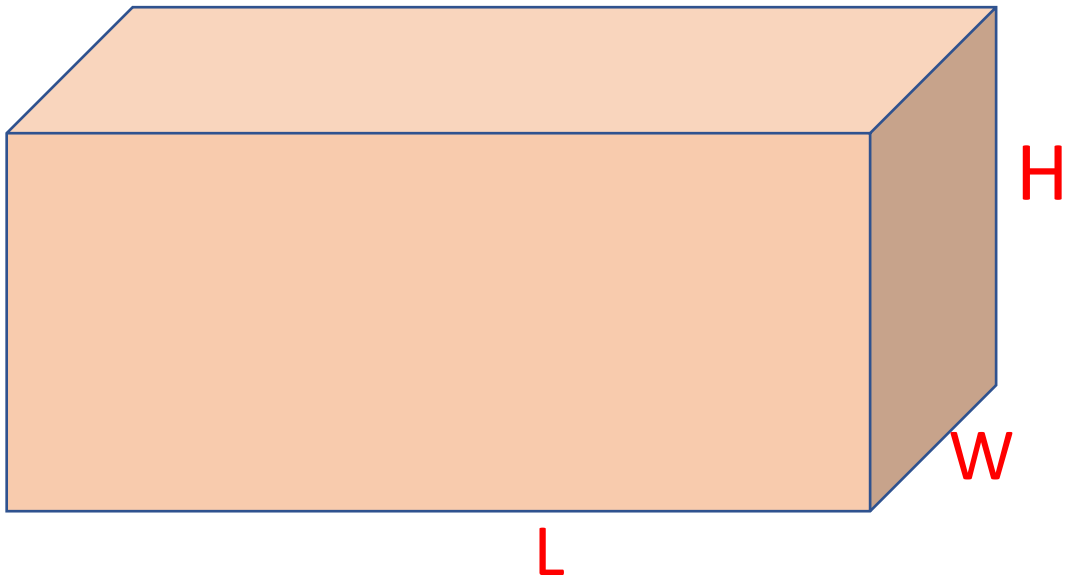
Rounding up…

Volume = 282,000 gallons

Volumes - Rectangles

Applications:

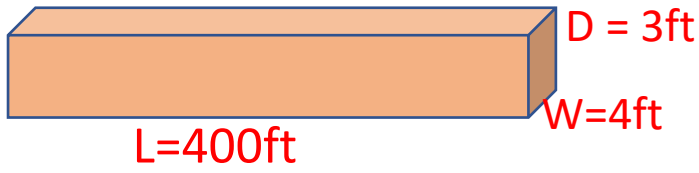
- Rectangular storage tanks
- Fill dirt and excavations
- Units: ft^3, yd^3



Volumes of Rectangles

Q: How many cubic yards of dirt must be ordered to fill in a trench of dimensions: L = 400 ft; W = 4 ft; D = 3 ft.

Vol = L X W X D



1ft = 12 inches

1 yd = 3 ft

1 yd³ = 27 ft³

Vol = L X W X D

Vol = 400 ft X 4 ft X 3 ft

Vol = 4800 ft³

Converting ft ³ to yd ³

27 **ft³** = 1 yd³

4800 **ft³ = ?**

$$\frac{4800\ \mathbf{ft^3} \times 1\ yd^3}{27\ \mathbf{ft^3}}$$

= 177.777

= 178 yd³

Water Pressure

- Pressure is a force per unit area
- Usually measured in pounds per square inch (PSI)
- Useful in managing water storage tanks (conversion: ft of water to psi and vice versa)
- Maintain a meaningful range based on your water system

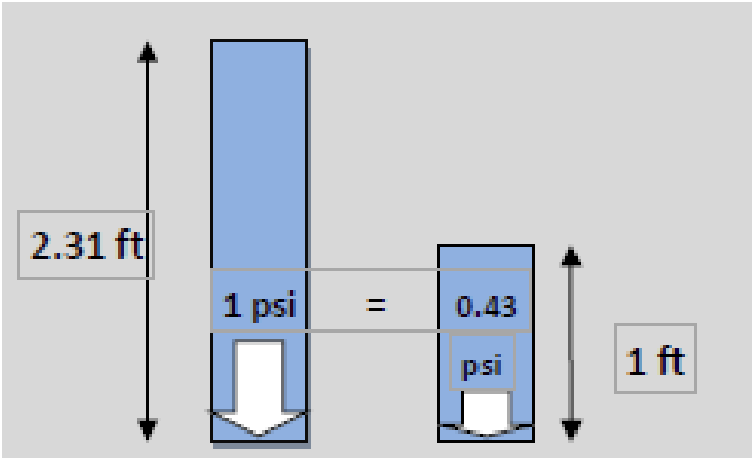
- Too low:
  - Water backflow - contamination concern
  - Lack of firefighting capacity
  - Customer complaints
- Too high:
  - Water main breaks
  - Increased turbidity: a contamination concern
  - Customer complaints

Water Pressure

Water Pressure Head

- When considering pressure in a water column, the column height is what matters (hydraulic head)

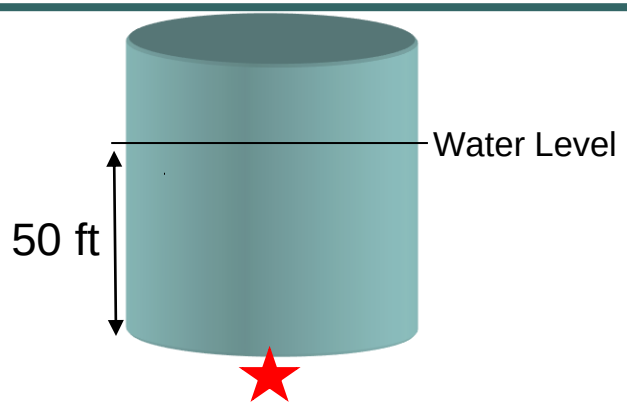
1 psi = 2.31 ft
1 ft = 0.433psi



Water Pressure

1 ft = 0.433psi
1 psi = 2.31 ft

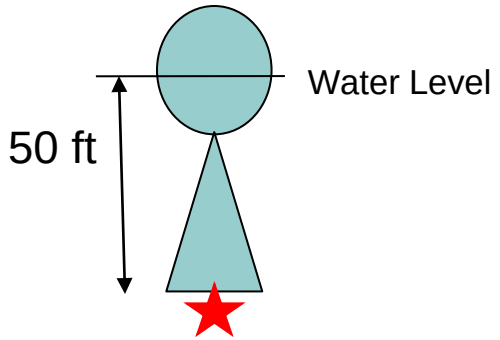
Q: What is the pressure (psi) at the bottom of each tank?



1 ft = 0.433 psi
50 ft = ?

$$\frac{50\ \cancel{ft} \times 0.433\ psi}{1\ \cancel{ft}}$$

= 22 psi



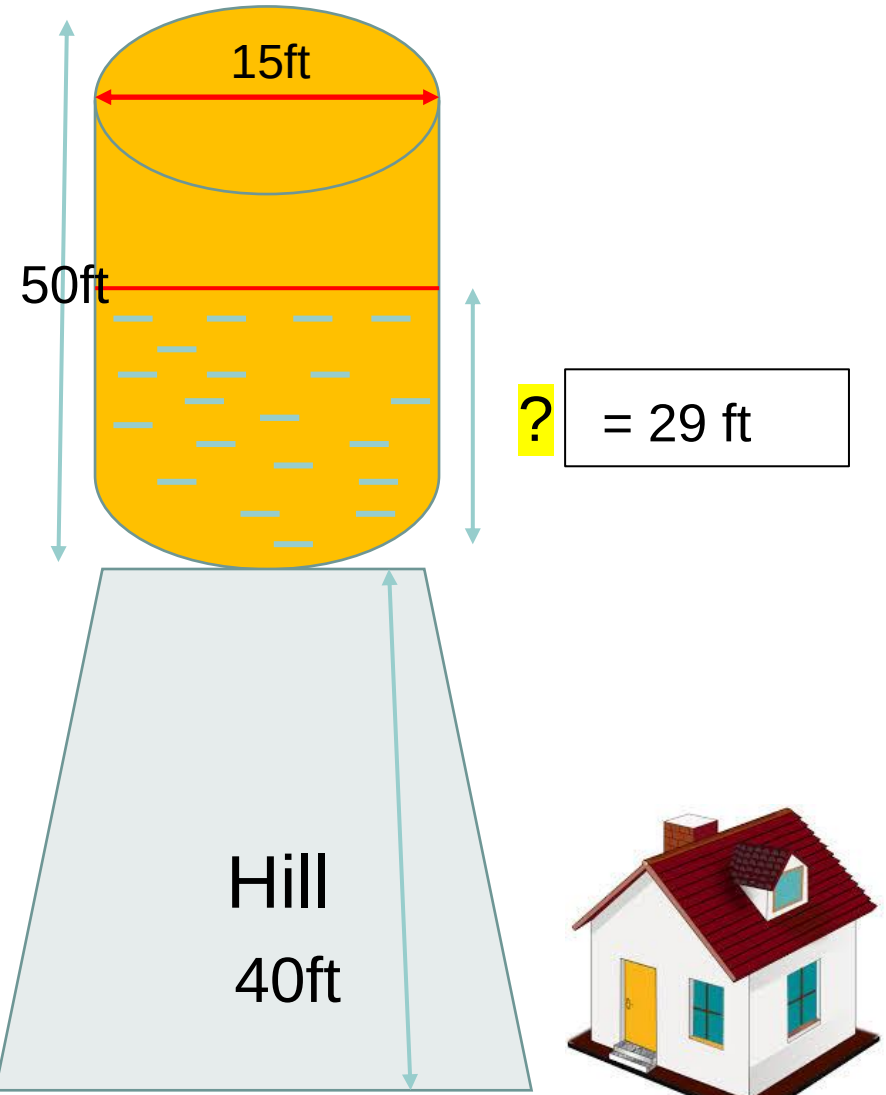
2.31 ft = 1 psi
50 ft = ?

$$\frac{50\ \cancel{ft} \times 1\ psi}{2.31\ \cancel{ft}}$$

= 22 psi

pressure depends on water head only (height of water)

Q: How much water is in the tank if the pressure reading at the first customer by the base of the hill is 30psi?



1 psi = 2.31 ft

Convert 30 psi to ft

1 psi = 2.31 ft

30 psi = ?

$$\frac{30\ \text{psi} \times 2.31\ \text{ft}}{1\ \text{psi}}$$

69.3ft

(Hill height + Water height in tank)

Water in tank alone

(Hill height + water height in tank) – (Hill height)

69.3ft – 40ft = 29.3ft

29 ft

Flow & Velocity

Flow = Area (cross-sectional) x Velocity

Flow (ft^3/sec) = Area (ft^2) x Velocity (ft/sec)

A volume

A length

Don’t confuse flow and velocity!

Q: Calculate the flow of water in a 6” pipe with a velocity of 10 ft/sec

Vel = 10 ft/sec

12” = 1ft

6” = 12/6 = 0.5 ft

D = 6” = 0.5ft
R = 3” = 0.25ft

Area = πR^2

Area = 3.14 x (0.25ft x 0.25ft)

Area = 0.196 ft^2

Flow (ft^3/sec) = Area (ft^2) x Velocity (ft/sec)

Flow (ft^3/sec) = 0.196 ft^2 x 10 ft/sec

Flow (ft^3/sec) = 1.96 ft^3/sec

Rounding up…

Flow = 2.0 ft^3/sec (CFS)

Important Chlorine Dosage & Feed Rate Formulas

1) Dosage, mg/l = (Demand, mg/l) + (Residual, mg/l)

2) Gas Cl_2 (lbs) = (Vol, MG) x (Dosage, mgl) x (8.34 lbs/gal)

3) HTH/Solid Cl_2 (lbs) = $\frac{\text{(Vol, MG) x (Dosage, mg/l) x (8.34 lbs/gal)}}{\text{(Decimal \% Strength)}}$

4) Liquid Cl_2 (lbs) = $\frac{\text{(Vol, MG) x (Dosage, mg/l) x (8.34lbs/gal)}}{\text{(Decimal \% Strength)}}$

Chlorine Dosage

1) Dosage, (mg/l) = Demand, (mg/l) + Residual, (mg/l)

(What you add) (What is used up) (What remains)

This equation can be re-arranged to solve for any of the three parameters. Isolate the unknown.

Understand this formula, because it is not always given on some formula sheets!

Chlorine Dosage

Q: Calculate the residual chlorine if the demand is 2.0 mg/L and the dosage is 2.8 mg/L

What do we have?

Demand = 2.0 mg/L

Dosage = 2.8 mg/L

Dosage = Demand + Residual

Isolate the unknown

Dosage - Demand = Demand + Residual - Demand

Residual = Dosage – Demand

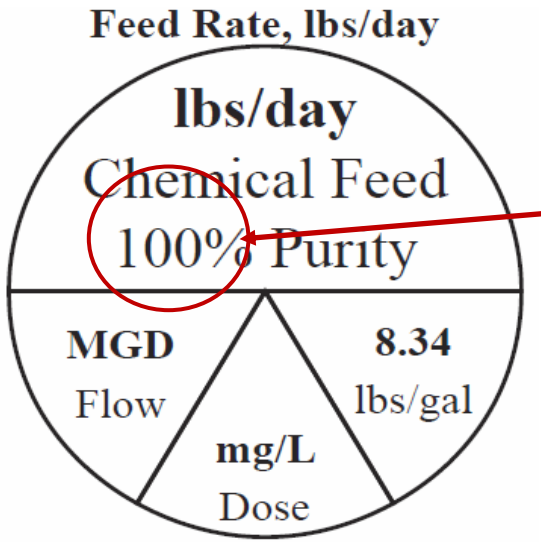
Residual = Dosage – Demand

Residual = 2.8 mg/l – 2.0 mg/L

Residual = 0.8 mg/L

Chemical Feed Rate & Dosage

a) Pie Wheel



Take note of the chemical strength!

b) Equation

Feed Rate (lbs/d) = Flow (MGD) x Dose (mg/L) x 8.34 lbs/gal

***This formula can apply to any water added chemical e.g. Fl, Cl_2 etc**

Chlorine Strengths

Gas Chlorine = 100% Strength

Solid Chlorine = ~65% Strength (Calcium Hypochlorite or HTH)
Decimal: 0.65

Liquid Chlorine = ~10 - 12.5% Strength (Sodium Hypochlorite)
Decimal: 0.125

Feed & Dosage

Q: How many lbs of Calcium Hypochlorite (HTH) should be used to treat a 700,000 gallon tank to get a residual Cl_2 of 1.5mg/L, when the demand is 2.6mg/L?

Dosage = Demand + Residual

Dosage = 2.6mg/L + 1.5mg/L

Dosage = 4.1 mg/L

Volume = 700,000 (0.7MG)

CL_2 (HTH) = 65% (0.65)

Feed Cl_2 (lbs) = $\frac{\text{(Vol, MG) x (Dosage, mg/l) x (8.34 lbs/gal)}}{\text{(Decimal \% Strength)}}$

Feed Cl_2 (lbs) = $\frac{\text{(0.7MG) x (4.1 mg/l) x (8.34 lbs/gal)}}{\text{(65/100)}}$

Feed Cl_2 (lbs) = $\frac{\text{(0.7MG) x (4.1 mg/l) x (8.34 lbs/gal)}}{\text{(0.65)}}$

= 36.8 lbs

Rounding up…. 37 lbs

Questions?

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