Example Problems

Let's work through some practical examples

Version & Date

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Segment topics:

- **Length, area & volumes**
- **Pressure**
- **Rates of flow & velocity**
- **Chemicals & Process**

Length, Area & Volumes

Get out your pencils, paper & calculators

Question:

If the maximum joint deflection on the bell and spigot joint of an 8-inch ductile iron pipe is 5^{o} , what is the deflection at the end of a stick of pipe with a lay length of 20 feet ?

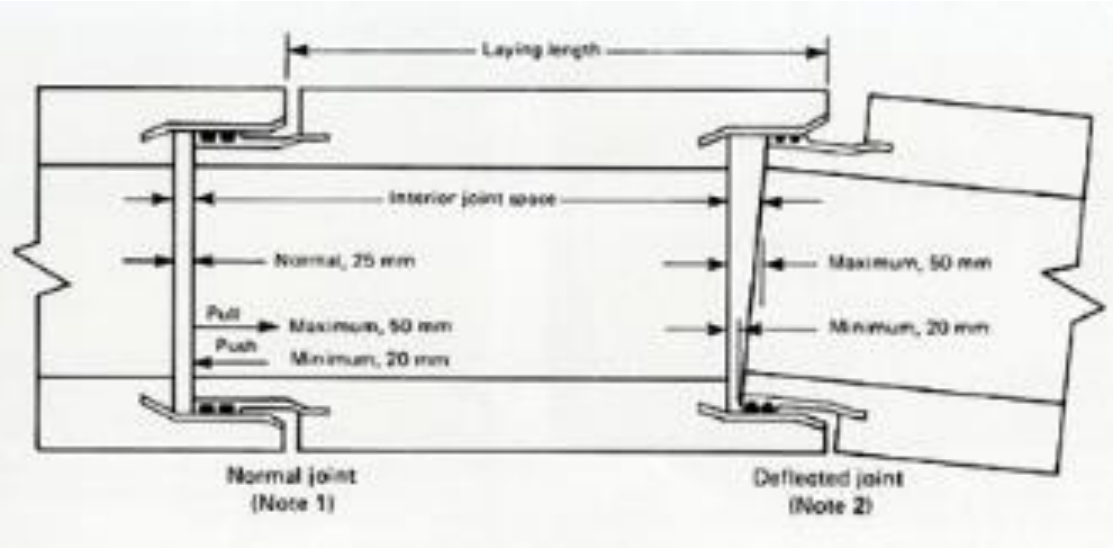


Photo from Electrosteel Castings, Ltd., Graphic from Ameron

Question:

If the maximum joint deflection on the bell and spigot joint of an 8-inch ductile iron pipe is 5^{o} , what is the deflection at the end of a stick of pipe with a lay length of 20 feet ?

20 feet x 12 inches / ft = 240 inches

Sine 5^{o} = 0.0872 *(dimensionless)*

240 inches x 0.0872 = 20.928 inches

~21 inches

Question:

If the maximum joint deflection on the bell and spigot joint of an 8-inch ductile iron pipe is 5^{o} , what is the deflection at the end of a stick of pipe with a lay length of 20 feet ?

Or:

Maximum Joint Deflection Full-Length Pipe—Pı*

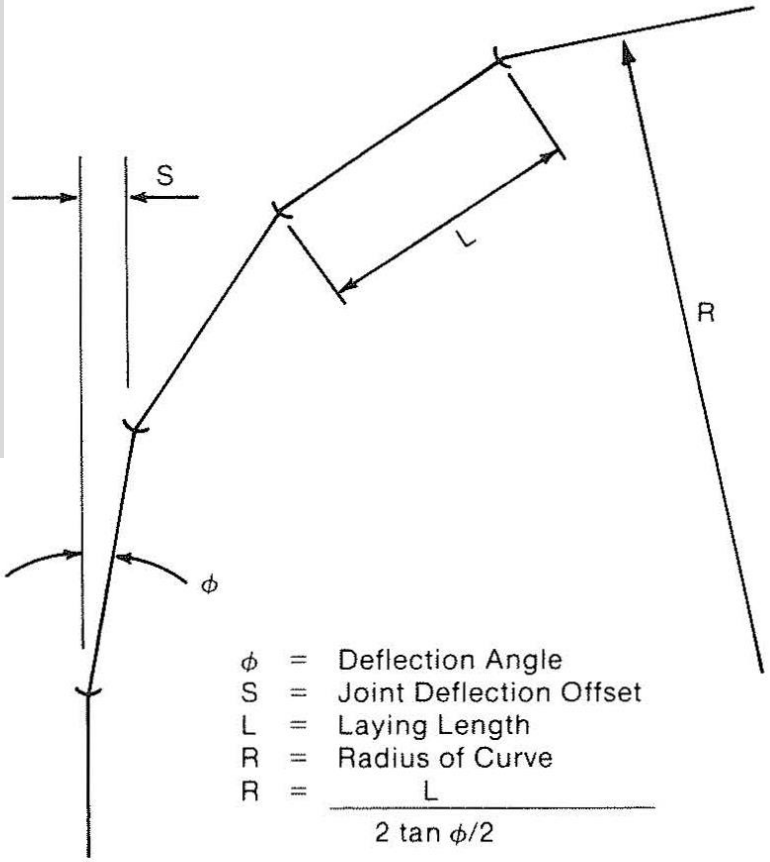
Nominal Pipe Size *in.*	Deflection Angle—θ *deg*	Maximum Offset—*S*† *in. (m)* 18 ft (5.5 m) *L*†	Maximum Offset—*S*† *in. (m)* 20 ft (6.1 m) *L*†
3	5	19 (0.48)	21 (0.53)
4	5	19 (0.48)	21 (0.53)
6	5	19 (0.48)	21 (0.53)
8	5	19 (0.48)	21 (0.53)
10	5	19 (0.48)	21 (0.53)
12	5	19 (0.48)	21 (0.53)
14	3*	11 (0.28)	12 (0.30)

Question:

If the formula for the radius of curvature for a pipe is:

L / 2 x tan (Φ/2)

What is the tightest radius for the 8-inch DIP with 20 foot lay length? L = lay length



Graphic from DIPRA

Figure 4. Pipeline Curve Geometry

Question:

If the formula for the radius of curvature for a pipe is

L / 2 x tan (Φ / 2)

What is the tightest radius for the 8-inch DIP with 20 foot lay length?

L = lay length

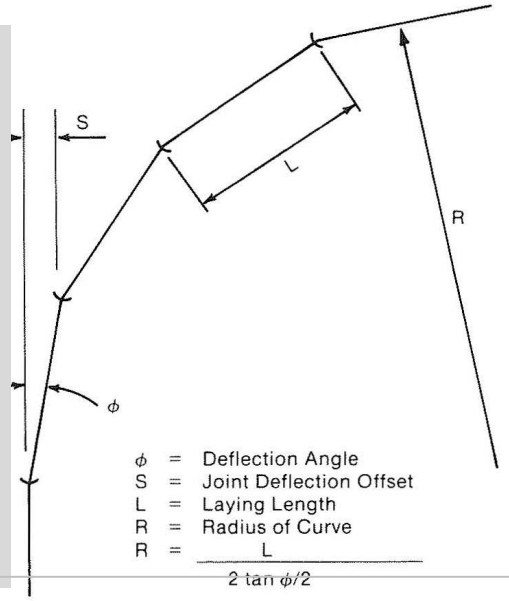


Figure 4. Pipeline Curve Geometry

Graphic from DIPRA

L = 20 feet , Φ = 5º

Tan (5 / 2) = 0.0437 *(dimensionless)*

20 feet / 2 x 0.0437 = 228.833 feet

~230 feet

Question:

Your new WTP will have 8 filter beds and you are planning on 7 being in service at any time. The flow rate is 8 gal/sf/min for clean bed and 6.5 for a bed that is ready for backwashing. If the beds will be close to square, what are the plan dimensions for a capacity of 40.0 mgd?

Photo from City of Lynden, WA

Question:

Filter Area

Average capacity = (8.0 + 6.5)/2 = 7.25g/sf/min

7.25 g/sf/min x 60 min/hr * 24 hr/d = 10,440 gal/sf/day

Area required = 40.0 mgd / 10,440 gal/sf/d = 3,831 sf

Area required / filter bed = 3,831 sf / 7 = 547 ft^2

Rough dimensions = $(547\ sf)^{0.5}$ = 23.4 ft / side

~ **20 ft * 28 ft = 560 sf** (multiples of 4 ft wide forms)

Question:

Your new reservoir is to have a active storage capacity of 1 MG and a pressure range of 25 psi. What is the diameter of the reservoir?

Graphic from City of Troutdale, OR

Question:

Tank diameter

Height range 25 psi x 2.31 ft/psi = 57.75 ft

Volume 1,000,000 gal./ 7.48 gal./ ft^3 = 133,690 ft^3

133,690 ft^3 / 57.75 ft = 2,415 ft^2 = tank area

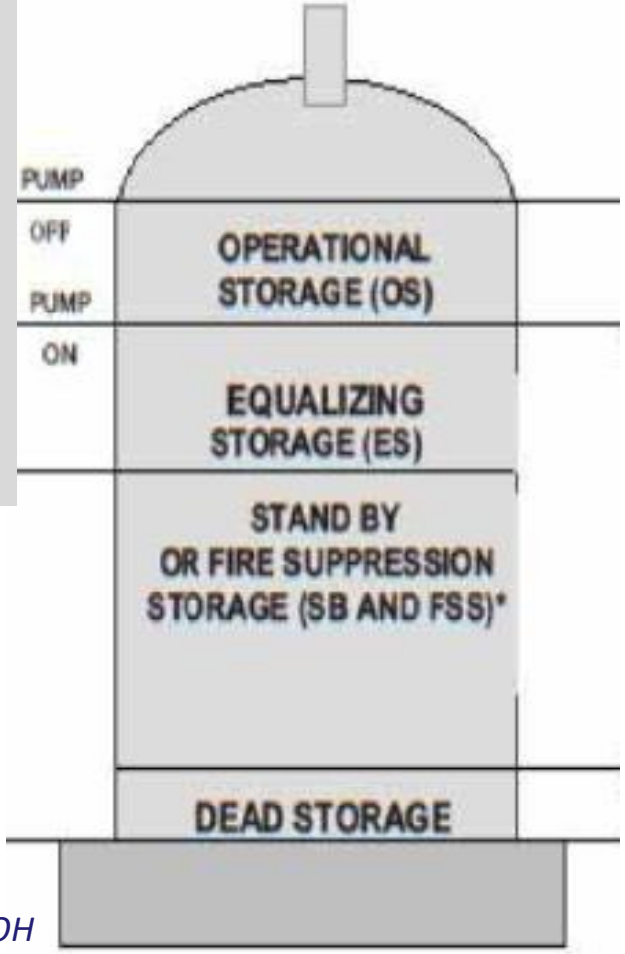
Area = D^2 x PI / 4 rearranged D = $(area * 4 / PI)^{0.5}$

$(2,415 * 4 / 3.14159)^{0.5}$ = 54.29 ft inside diameter

~55 ft

Question:

You've been given a screaming good deal for a new water tank but the Canadian contractor wants to do the job in metric units. You need 500,000 gallons of storage (operational + equalizing + standby). The proposed tanks is 12 meters in diameter x 20 meters to the overflow. Is the tank big enough? If yes, what is the volume of the dead storage?



Graphic from WSDOH

Question:

Is the tank big enough?

Area = 12^2 * 3.14159 / 4 = 113.10 m^2

Volume = 113.10 m2 x 20 m = 2,262 m^3

Volume conversion 264.172 gallons / m^3

2,263 ~~m^3~~ x 264.172 gallons / ~~m^3~~

597,543 gallons – **YES** big enough

597,543 gal. – 500,000 gal. = 97,543 gal excess

Question:

A lime tank is a cone at the bottom and cylindrical at the top. The cylinder portion is 28 feet tall. The cone has a minimum diameter of 2 feet and is 12 feet tall. What is the volume of the tank in cubic feet to 3 significant figures?

Question:

A lime tank is a cone at the bottom and cylindrical at the top. The cylinder portion is 28 feet tall. The cone has a minimum diameter of 2 feet and is 12 feet tall. What is the volume of the tank in cubic feet to 3 significant figures?

Cylinder volume = Π x d^2 / 4 x H

Cone volume = (d_1^2 + d_2^2) / 2 x Π/4 x H

Π x 15^2 / 4 x 28 + (15^2+2^2)/2 x Π/4 X H

6,030 ft3

Question:

Convert 16,912,000 liters to acre-feet

Photo from the Town of Friday Harbor

Question:

Convert 16,912,000 liters to acre-feet

Liters → gallons → cubic feet → acre-feet

16,912,000 liters x 0.2642 gal/liter = 4,468,150 gal

4,468,150 gallons / 7.48 gallons/cf = 597,346 cf

597,346 cf / 43,560 cf/acre-feet = 13.7138 acre-ft

13.7 acre-feet

Question:

A new section of pipe is 16” in diameter and 550 feet long. How many gallons does the pipe contain? And why do we care?

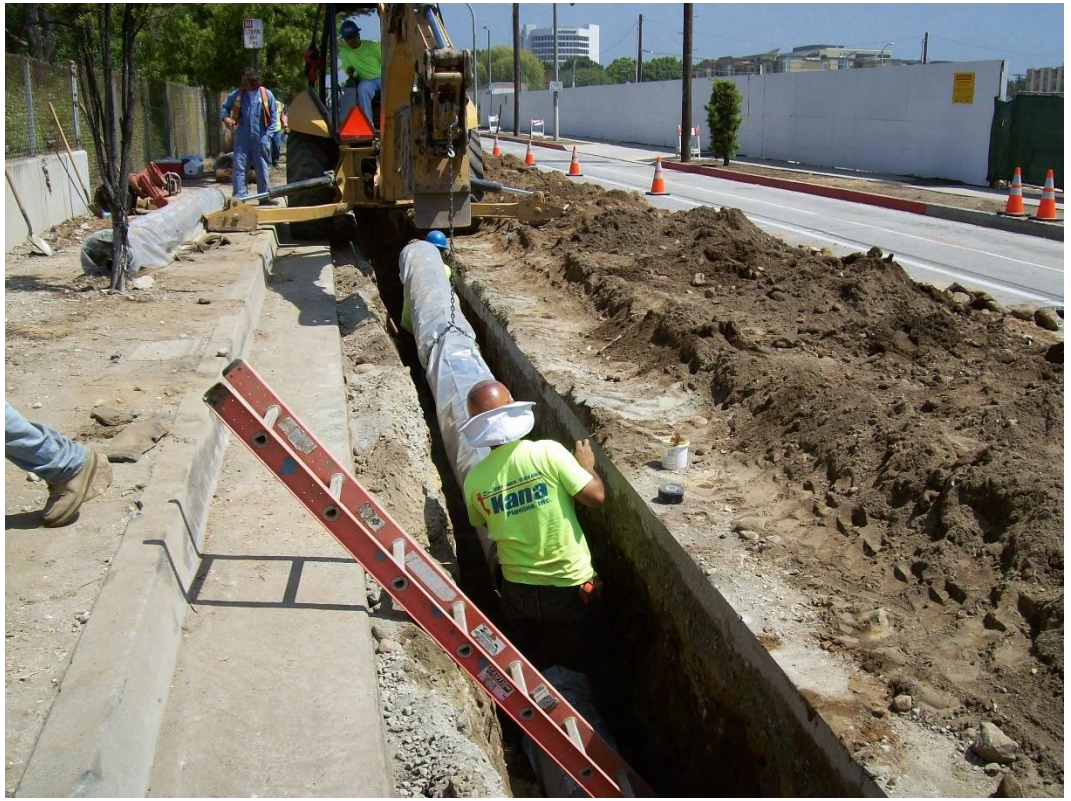


Photo from Kana Pipeline, Inc.

Question:

A pipe is 16” in diameter and 550 feet long. How many gallons does the pipe contain?

$1.33\ ft^2 \times PI / 4 \times 1\ ft = 1.39\ ft^3 / ft$

$1.39\ ft^3 / ft \times 550\ ft = 764.11\ ft^3$

$764.11\ ft^3 \times 7.48\ gal. / ft^3 = 5{,}715.5\ gallons$

5,715.5 gallons – *round off to 5,720 gallons*

Question:

What is the diameter of a tank with a circumference of 408.2 ft?

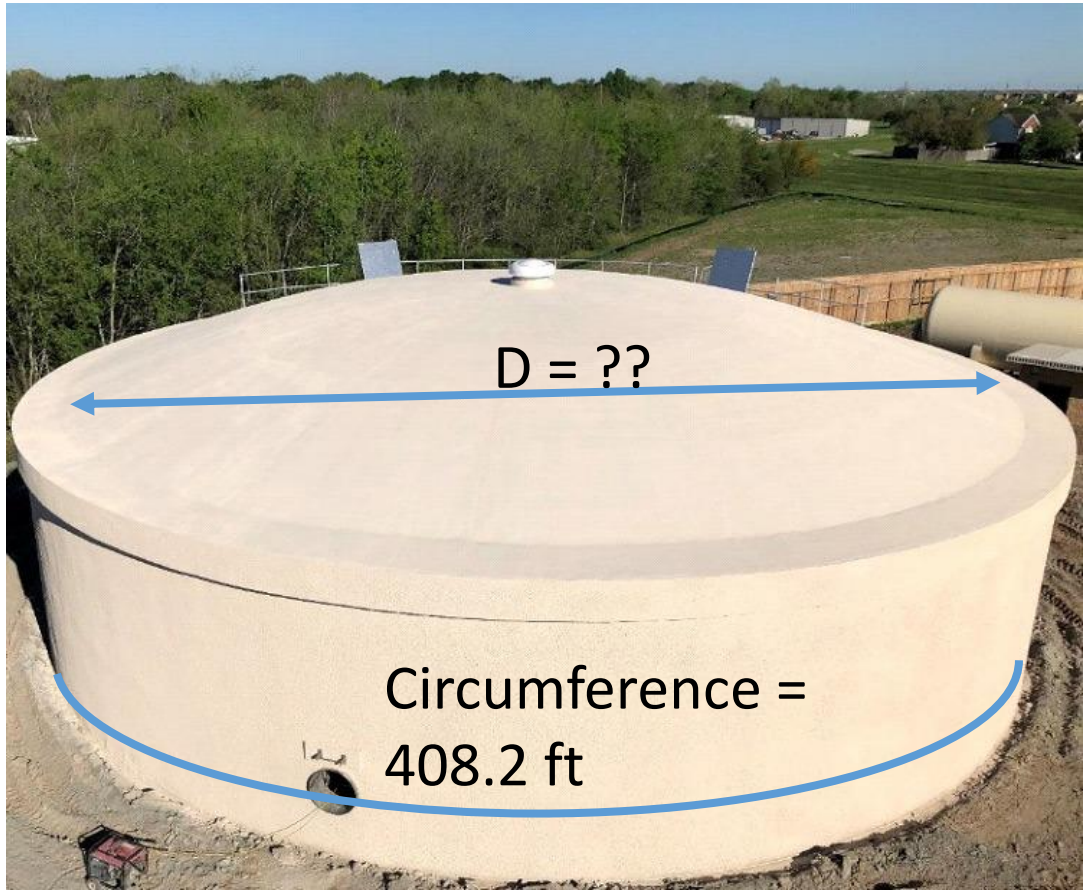


Photo from DN Tanks

Question:

What is the diameter of a tank with a circumference of 408.2 ft?

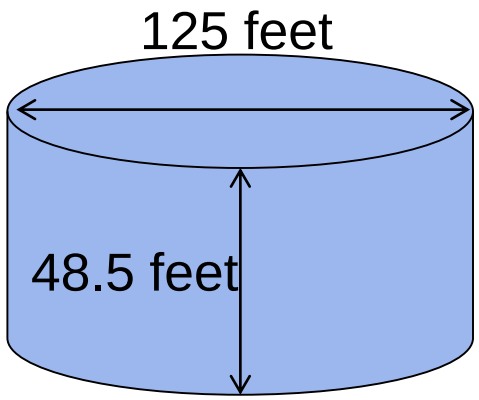
408.2 feet / pi = 408.2 feet / 3.14159 =

= 129.93 feet in diameter

~130 feet

Question:

What is the internal surface area of a cylindrical tank (bottom, top, and the cylinder wall), if it is 125.0 ft in diameter and 48.5 ft high



Top = Area 1

Area 1 = $0.785*dia^2$

Area 1 = $0.785 \times (125\ ft)^2$

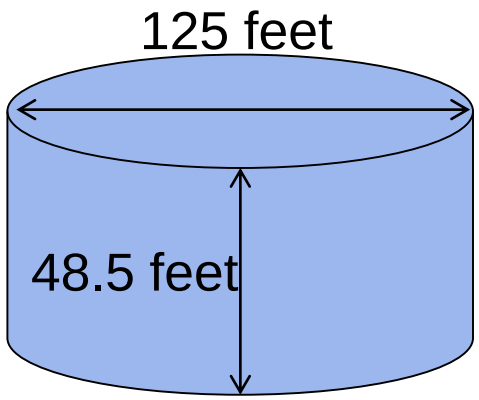
Area 1 = 12,265 sq ft

Top & Bottom = 2 x 12,265 sq ft

Top & Bottom = 24,530 sq ft

Question:

What is the internal surface area of a cylindrical tank (bottom, top, and the cylinder wall), if it is 125.0 ft in diameter and 48.5 ft high



Cylinder wall = Area 2

Area 2 = circumference x ht

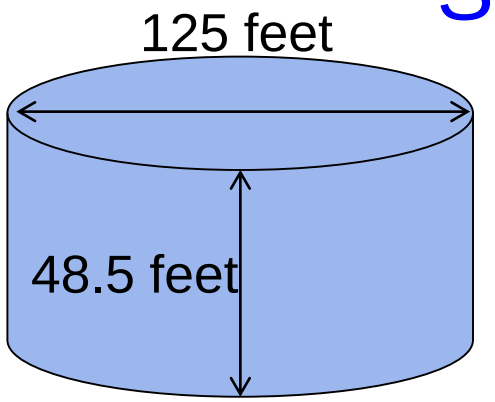
Area 2 = Π x diameter x ht

Area 2 = 3.14 x 125 x 48.5

Area 2 = 19,036 sq ft

Question:

What is the internal surface area of a cylindrical tank (bottom, top, and the cylinder wall), if it is 125.0 ft in diameter and 48.5 ft high



Surface area = 2 x Area1 + Area2

= 24,530 sq ft +19,036 sq ft

= 43,566 sq ft

43,600 sq ft

Pressure

Often the limiting factor

Question:

What is the pounds per square inch pressure at the bottom of a tank, if the water level is 38.29 ft.?

Photo from City of Marysville

Question:

What is the pounds per square inch pressure at the bottom of a tank, if the water level is 38.29 ft.?

1 foot of water = 0.433 psi

38.29 ft * 0.433 psi / ft water = 16.6 psi

16.6 psi ~ 17 psi

Question:

The pressure at a fire hydrant is 171 feet. What is the pressure in pounds per square inch (psi)?

Photo from City of Palm Springs

Question:

The pressure at a fire hydrant is 171 feet. What is the pressure in pounds per square inch (psi)?

= 171 ft / 2.31 psi/ ft

74 psi

Question:

What is the pressure head at a fire hydrant in feet, if the pressure gauge reads 121 psi

Photo by Jeff Lundt

Question:

What is the pressure head at a fire hydrant in feet, if the pressure gauge reads 121 psi

1 foot of water = 0.433 psi

121 psi / 0.433 psi / ft water = 279.45 ft

~280 ft

Question:

W & WW

Determine the pressure in psi at the bottom of an alum storage tank if the tank's level is 8.95 feet and alum density is 11.32 lb / gallon

Photo from DN Tanks

Question:

Determine the pressure in psi at the bottom of an alum storage tank if the tank's level is 8.95 feet and alum density is 11.32 lb / gallon

Pressure is the weight of the fluid above the point of measurement

11.32 lb/gallon x 7.48 gallons/cf = 84.67 lb/cf

8.95 feet x 84.67 lb/cf = 757.8 lb/sf

757.8 lb/sf / 144 in^2/sf = 5.2625 lb/in^2 or psi

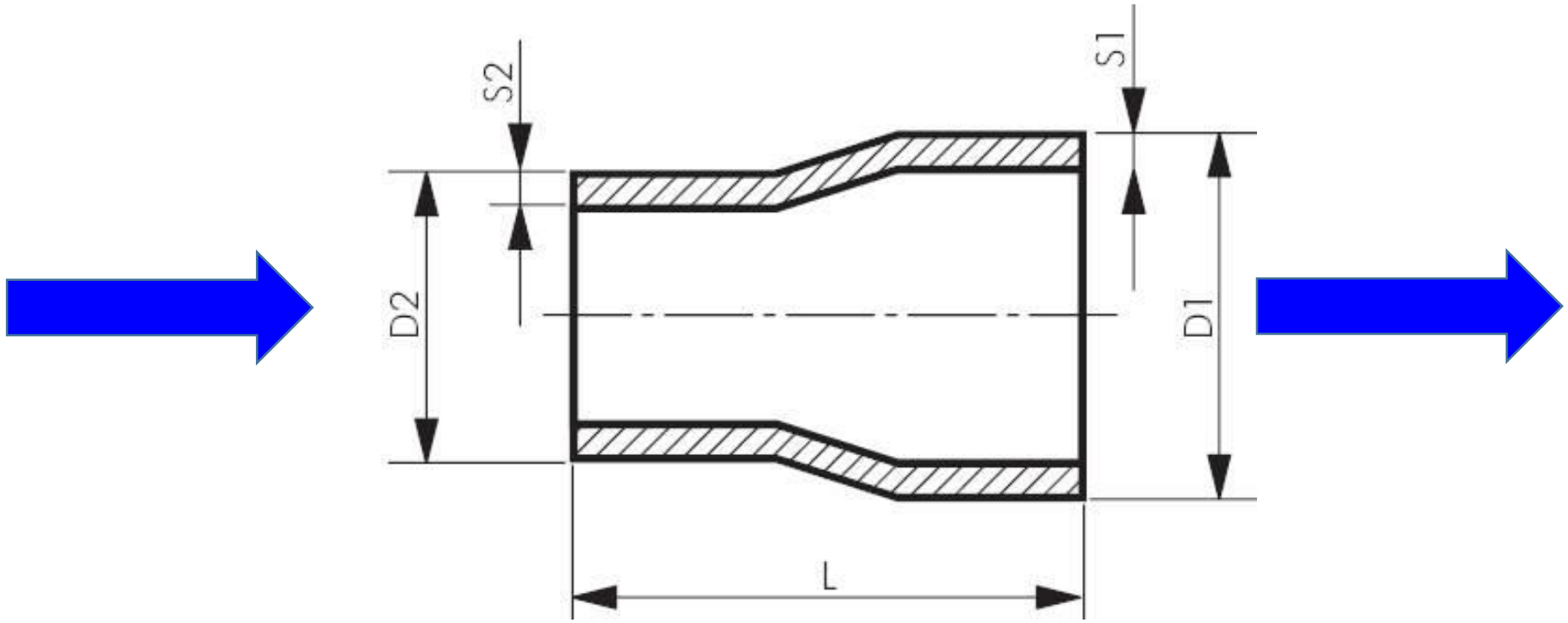
5.26 psi

Rates of Velocity & Flow

How fast?

Question:

Water flows at a velocity of 3.75 fps in a 10-in. diameter pipe. If the pipe changes from the 10-in. to a 12-in. pipe, what will the velocity be in the 12-in. pipe?



Question:

Water flows at a velocity of 3.75 fps in a 10-in. diameter pipe. If the pipe changes from the 10-in. to a 12-in. pipe, what will the velocity be in the 12-in. pipe?

Use the ratio of the areas (w/o pi & constant)

$10^2 / 12^2 = 100 / 144 = 0.694$

3.75 fps x 0.694 = 2.60 fps

2.6 fps

Question:

Water is flowing in a pipeline at a rate of 2.65 cu/ft per sec. What is the flow rate in gallons per min.?

Question:

Water is flowing in a pipeline at a rate of 2.65 cu.ft. per sec. What is the flow rate in gallons per min.?

2.65 cfs x 7.48 gal/cf x 60 sec/min. =
1,189.3 gpm

1,190 gpm

Question:

An 18-inch diameter distribution pipe delivers 988,000 gallons in 24 hours. What is the average velocity during the 24 hour period in feet / second?

Photo from 123RF.com

Question:

An 18-inch diameter distribution pipe delivers 988,000 gallons in 24 hours. What is the average flow during the 24 hour period in feet / second?

$(18 \text{ inches} / 12 \text{ inch / ft})^2 \times PI / 4 = 1.77 \text{ sf}$

$24 \text{ hr} \times 60 \text{ min / hr} \times 60 \text{ sec / min} = 86{,}400 \text{ sec}$

$988{,}000 \text{ gal} / 7.48 \text{ ft}^3 / \text{gal} = 132{,}085.6 \text{ ft}^3$

$132{,}085.6 \text{ ft}^3 / 1.77 \text{ sf} / 86{,}400 \text{ sec} =$

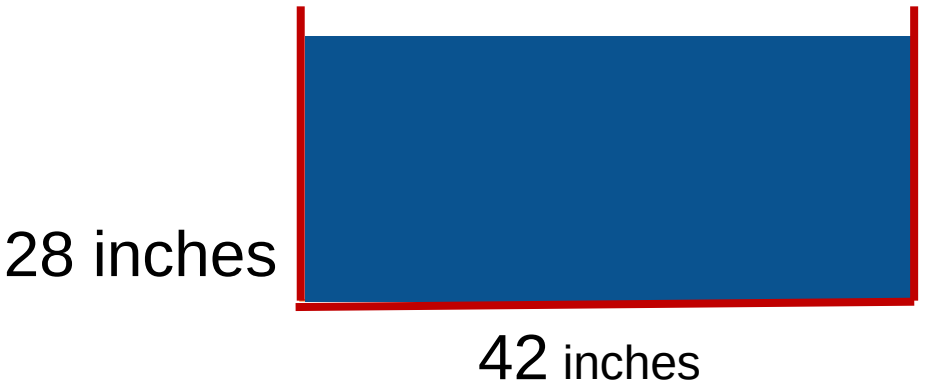
0.87 ft / sec

Question:

A rectangular section channel is 42” wide and the water is a depth of 28”. You toss a float in and determine that it travels 30 feet in 15 seconds. What is the flow rate in ft^3/sec? gpm?

Dimensions in inches, change to feet

Flow = Velocity x Area



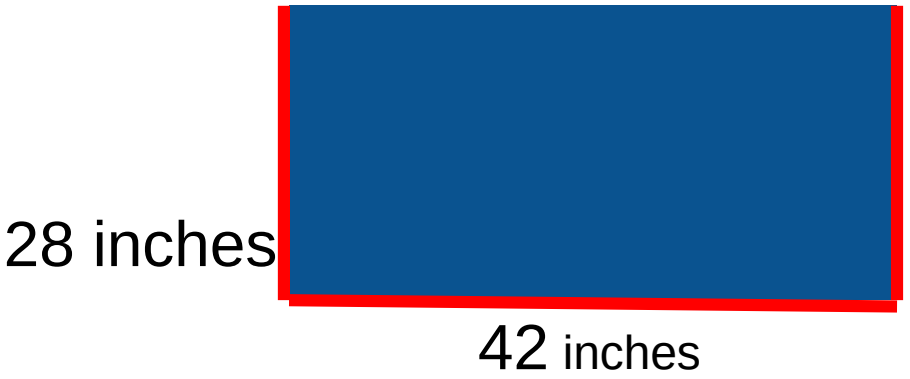
$$\text{Width} = \frac{42 \text{ in}}{12 \text{ in}} \left| \frac{1 \text{ ft}}{} \right. = 3.5 \text{ ft}$$

$$\text{Depth} = \frac{28 \text{ in}}{12 \text{ in}} \left| \frac{1 \text{ ft}}{} \right. = 2.3 \text{ ft}$$

Question:

A channel is 42” wide and the water is a depth of 28”. You toss a float in and determine that it travels 30 feet in 15 seconds. What is the flow rate in ft^3/sec? gpm?

Flow = Velocity x Area



Area = 2.3 ft x 3.5 ft

Area = 8.05 sq ft

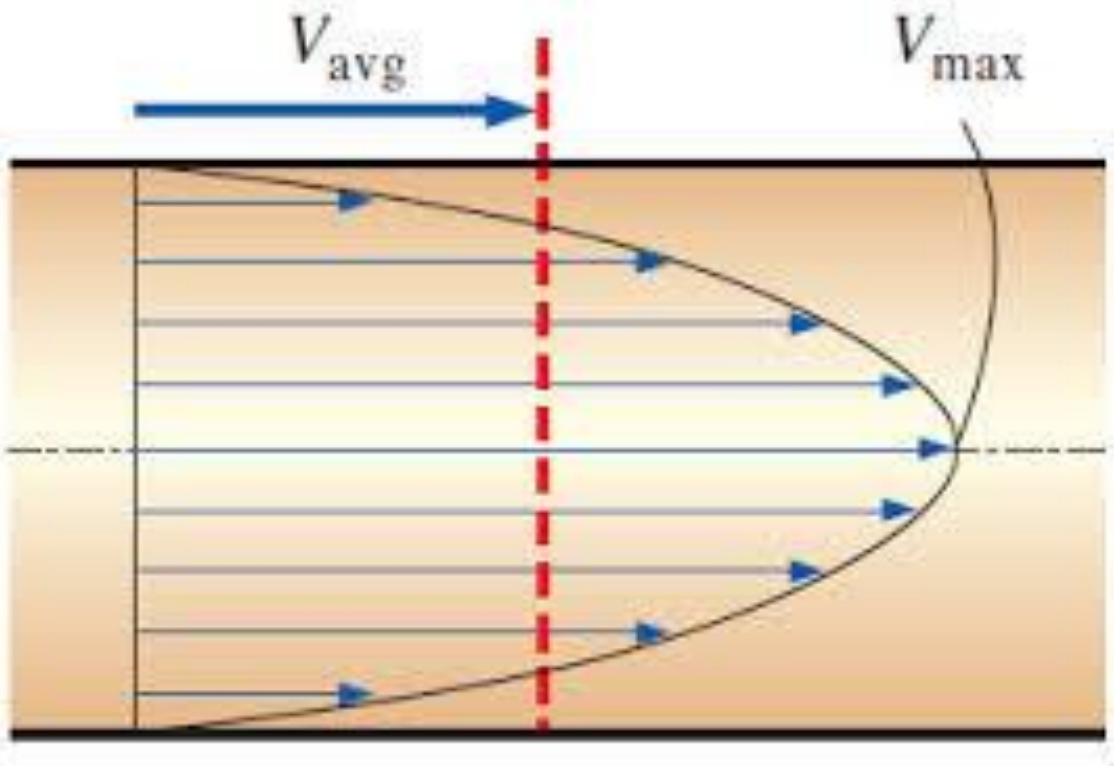
$$\text{Velocity} = \frac{30 \text{ feet}}{15 \text{ seconds}} = 2 \text{ fps}$$

Flow = 2 fps x 8.05 sq ft

Flow rate = 16.1 cfs

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?



Graphic from drive.uqu.edu.sa

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

Flow (Q) = Velocity x Area

600 gpm = Velocity x $(.67\ ft)^2$ x .785

8 inches = 8/12 foot
= .67 foot

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

Flow (Q) = Velocity x Area

$600\ gpm = Velocity \times (.67\ ft)^2 \times .785$

$$\frac{600\ gpm}{(.67\ ft)^2 \times .785} = \frac{Velocity \times (.67\ ft)^2 \times .785}{(.67\ ft)^2 \times .785}$$

8 inches = 8/12 foot
= .67 foot

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

Flow (Q) = Velocity x Area

$$600\ \text{gpm} = \text{Velocity} \times (.67\ \text{ft})^2 \times .785$$

$$\frac{600\ \text{gpm}}{(.67\ \text{ft})^2 \times .785} = \frac{\text{Velocity} \times (.67\ \text{ft})^2 \times .785}{(.67\ \text{ft})^2 \times .785}$$

$$\frac{600\ \text{gal}}{\text{min}} \left| \frac{1\ \text{cu ft}}{7.48\ \text{gal}} \right. = 80.2\ \text{cfm}$$

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

Flow (Q) = Velocity x Area

$$600\ gpm = Velocity \times (.67\ ft)^2 \times .785$$

$$\frac{600\ gpm}{(.67\ ft)^2 \times .785} = \frac{Velocity \times (.67\ ft)^2 \times .785}{(.67\ ft)^2 \times .785}$$

$$\frac{600\ gal}{min} \left| \frac{1\ cu\ ft}{7.48\ gal} \right. = 80.2\ cfm \Rightarrow \frac{80.2\ cu\ ft}{min} \left| \frac{1\ min}{60\ sec} \right. = 1.3\ cfs$$

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

$$\text{Flow (Q)} = \text{Velocity} \times \text{Area}$$

$$600 \text{ gpm} = \text{Velocity} \times (.67 \text{ ft})^2 \times .785$$

$$\frac{600 \text{ gpm}}{(.67 \text{ ft})^2 \times .785} = \frac{\text{Velocity} \times (.67 \text{ ft})^2 \times .785}{(.67 \text{ ft})^2 \times .785}$$

$$\frac{600 \text{ gal}}{\text{min}} \Big| \frac{1 \text{ cu ft}}{7.48 \text{ gal}} = 80.2 \text{ cfm}$$

$$\frac{80.2 \text{ cu ft}}{\text{min}} \Big| \frac{1 \text{ min}}{60 \text{ sec}} = 1.3 \text{ cfs}$$

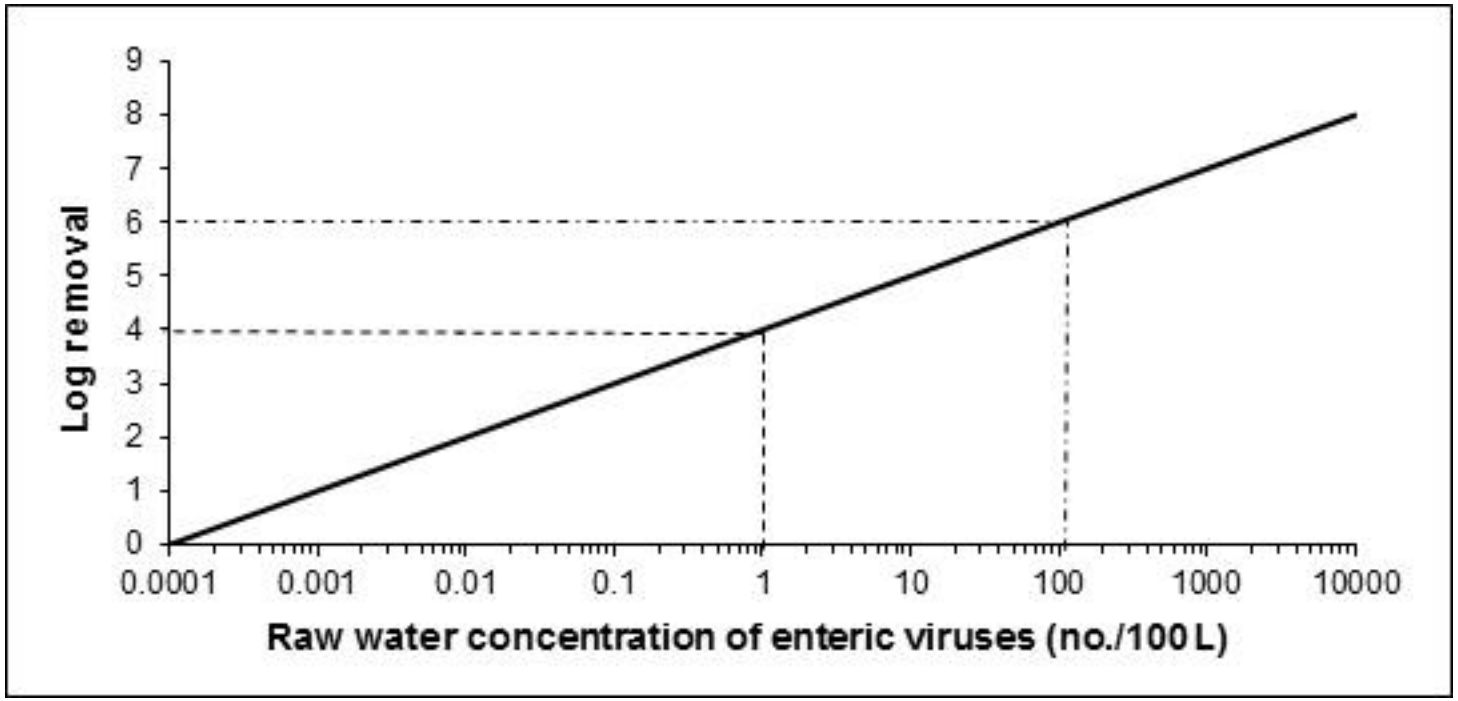
$$\frac{1.3 \text{ cfs}}{(0.67 \text{ ft})^2 \times 0.785} = \text{Velocity} = \mathbf{3.7 \text{ ft/sec}}$$

Chemicals & Process

More of the same but with a twist

Question:

Calculate the log removal for a water treatment plant if the samples show a raw water coliform count of 295/100 ml (through extrapolation) and the finished water shows 2/100 ml?



Graphic from Health Canada

Question:

Calculate the log removal for a water treatment plant if the samples show a raw water coliform count of 295/100 ml (through extrapolation) and the finished water shows 2/100 ml?

295 / 2 = 147.5

Log10 (147.5) = 2.1688 ~ 2.2

2.2 log removal

Question:

A 10 foot inside diameter chemical tank drops 4.31 inches in exactly 3 hours. What's the pumping rate for the chemical in gpm?

Photo from City of Anacortes

Question:

A 10 foot inside diameter chemical tank drops 4.31 inches in exactly 3 hours. What's the pumping rate for the chemical in gpm?

10 ft^2 x Π /4 = 78.53 sf

4.31 inches / 12 inches / ft = 0.3592 ft

78.53 sf x 0.3592 ft x 7.48 gal / ft^3 = 210.98 gal.

210.98 gal / 3 hr / 60 min./hr = 1.17 gpm

1.17 gpm

Question:

How many pounds per day of 65% calcium hypochlorite are required for maintaining a 2.5 mg/l dosage for a 2,575 gpm treatment plant?

Photo from Kemcore

Question:

How many pounds per day of 65% calcium hypochlorite are required for maintaining a 2.5 mg/l dosage for a 2,575 gpm treatment plant?

2.5 mg / L / 0.65% = 3.85 mg calcium hypo / L

3.85 mg/ L / 1000 mg / g / 1000 g / kg x 2.2 lb / kg / 0.264 L / gallon = 3.45×10^{-5} lb / gallon

2,575 gpm x 60 min/hr x 24 hr/day = 3.71×10^{6} gpd

3.71×10^{6} gpd x 3.45×10^{-5} lb / gallon

120 lb / day

Question:

Determine the percent mineral rejection from a reverse osmosis plant if the feedwater contains 1,230 mg/l total dissolved solids (TDS) and the product water contains 135 mg/l TDS.

Photo from Seattle Yacht Club, Henry Island

Question:

Determine the percent mineral rejection from a reverse osmosis plant if the feedwater contains 1,230 mg/l total dissolved solids (TDS) and the product water contains 135 mg/l TDS.

(1 – (135mg/l /1,230 mg/l)) = 0.8902 x 100
= 89.02%

Note all the units are the same and cancel (mg/l) so we get a unitless number as a ratio and assign % to it.

~89 percent

Question:

A 1.81 MG reservoir is being disinfected with a chlorine dosage of 9.75 mg/l. If the sodium hypochlorite is 11.5% available chlorine, how many pounds are needed?

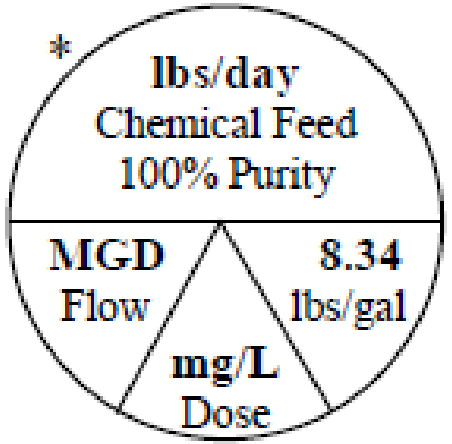
Photos from Roche Harbor & Silver Lake Water & Sewer District

Question:

A 1.81 MG reservoir is being disinfected with a chlorine dosage of 9.75 mg/l. If the sodium hypochlorite is 11.5% available chlorine, how many pounds are needed?

Use the wheel!

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34 \text{ lbs/gal})}{(\text{Purity, decimal percentage})}$$



$$= \frac{1.81 \text{ MG} \times 9.75 \text{ mg/l} \times 8.34 \text{ lb/gallons}}{0.115 \text{ (Purity in decimal)}}$$

$$= 1280 \text{ lbs}$$

Question:

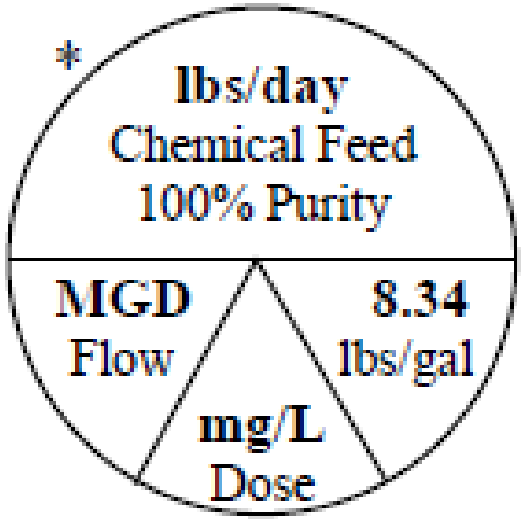
How many pounds of chlorine gas are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L?

Photo from City of Anacortes

Question:

How many pounds of chlorine gas are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\ \text{lbs/gal})}{(\text{Purity, decimal percentage})}$$



Pounds =

$$\frac{4\ \text{MG} * 2\ \text{mg/l} * 8.34\ \text{lbs/gal}}{1.0\ \text{purity}}$$

Answer is 67 lb

Question:

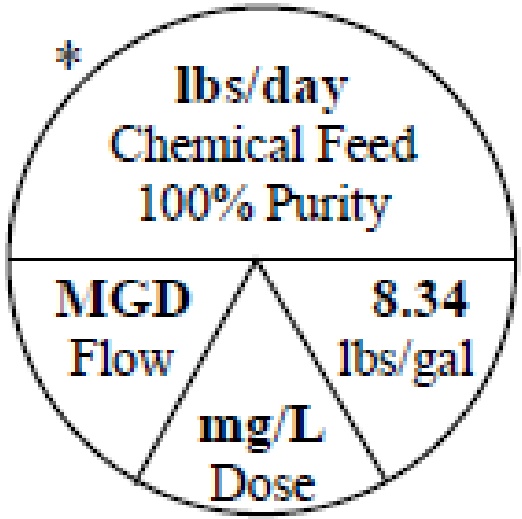
How many pounds of 12.5% sodium hypochlorite is necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L?

Photo from City of Marysville

Question:

How many pounds of 12.5% sodium hypochlorite is necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\,\text{lbs/gal})}{(\text{Purity, decimal percentage})}$$



$$\text{Pounds} = \frac{4\ \text{MG} * 2\ \text{mg/l} * 8.34\ \text{lbs/gal}}{0.125\ \text{purity}}$$

Answer is 534 lb (533.76)

Question:

How many pounds of 0.8% onsite generated sodium hypochlorite are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L?

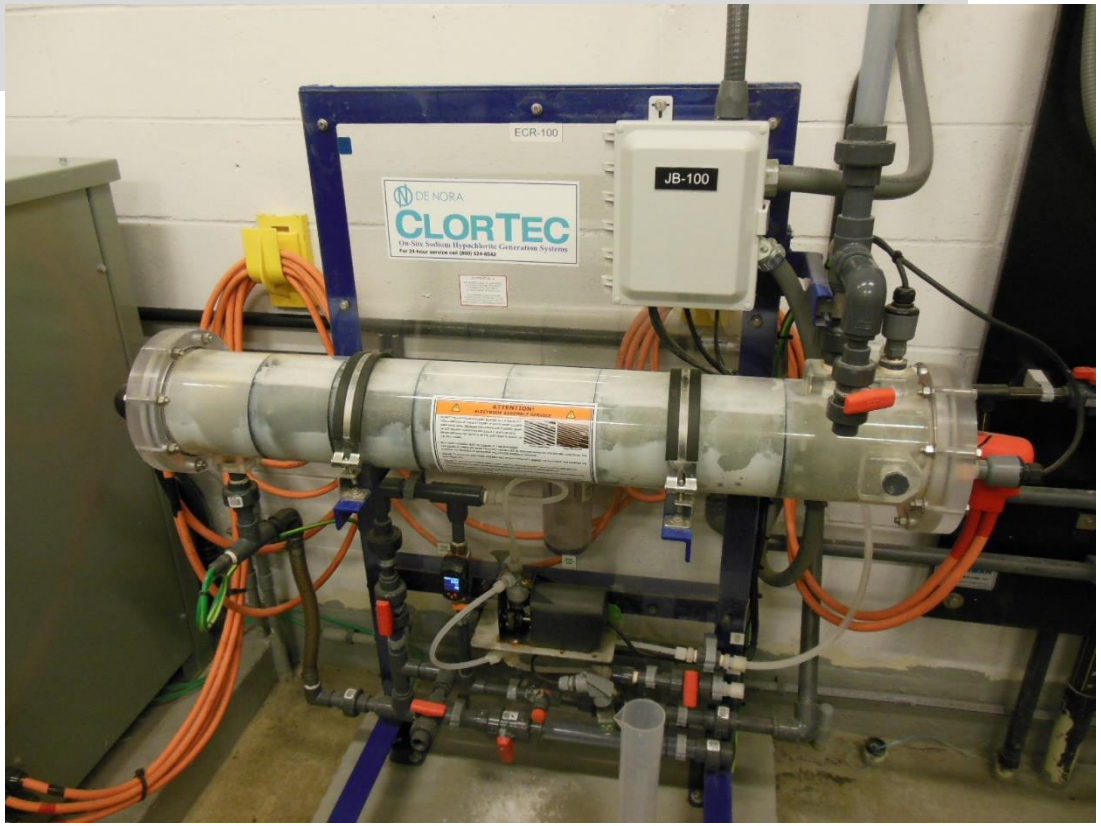
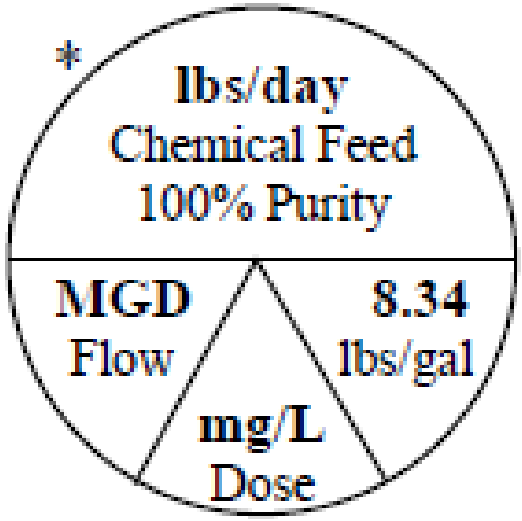


Photo from City of Marysville

Question:

How many pounds of chlorine gas are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\ \text{lbs/gal})}{(\text{Purity, decimal percentage})}$$



Pounds =

$$\frac{4\ \text{MG} * 2\ \text{mg/l} * 8.34\ \text{lbs/gal}}{0.008\ \text{purity}}$$

Answer is 8,340 lb (= 1,115 gallons)

Questions, Comments and Suggestions?

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Section title

subtitle

Header

- Tier 1 info
  - Tier 2 info
    - Tier 3 info

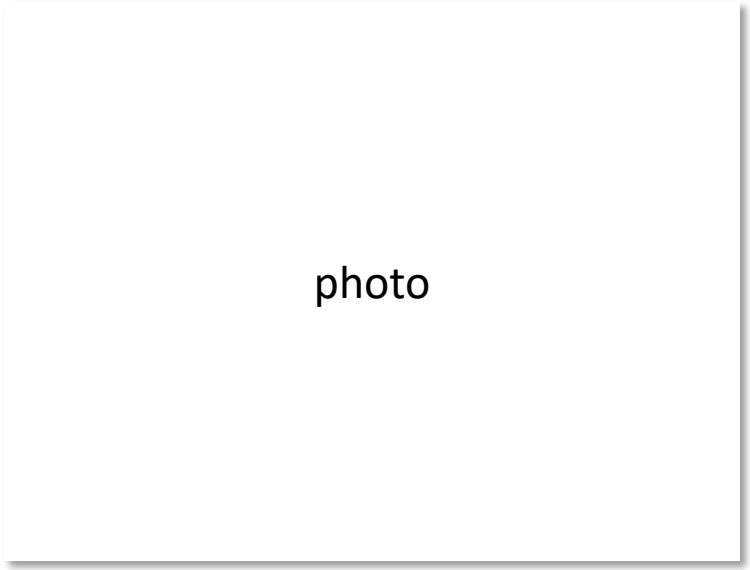


Photo caption

Optional text here

Header

- Tier 1 info
  - Tier 2 info
    - Tier 3 info

Photo caption

Header

Case A

- info

Case B

- info

Header

	Col 1	Col 2	Col 3	Col 4
This	X	X	X	X
That	X	X	X	X
The	X	X	X	X
Other	X	X	X	X
Thing	X	X	X	X