Tennessee Operator Certification Formula Manual

Distribution Systems Formulas & Conversions

Prepared by the Fleming Training Center

About This Manual

This publication is provided by the Tennessee Department of Environment and Conservation (TDEC), Division of Water Resources (DWR), as an official resource for examinees participating in the State of Tennessee's operator certification program. It may be used during certification exams and is intended to support operators in understanding and applying essential mathematical formulas and conversions in the field.

This manual was collaboratively developed and reviewed by:

- **Fleming Training Center (FTC) –** content development and formatting
- **Water Professionals International (WPI) –** foundational formula reference materials
- **Tennessee Association of Utility Districts (TAUD) –** editorial review and industry input

This resource is intended to reflect Tennessee's commitment to operator preparedness and professional excellence. While based on national standards, the formatting and presentation have been tailored to meet the needs of Tennessee operators and exam settings.

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Circumference and Perimeter

Circumference of a Circle = (3.14)(Diameter)

Perimeter, ft = (2)(Length, ft) + (2)(Width, ft)

Area

Area of a Circle*, ft^2 = (0.785)$(\text{Diameter, ft})^2$

Area of a Circle, ft^2 = (3.14)$(\text{Radius, ft})^2$

Area of a Rectangle*, ft^2 =(Length, ft)(Width, ft)

Area of a Right Triangle*, ft^2 = $\frac{[(\text{Base, ft})(\text{Height, ft})]}{2}$

Lateral Surface Area of a Cone, ft^2 = (3.14)(Radius, ft)($\sqrt{(\text{Radius, ft})^2+(\text{Height, ft})^2}$)

Total Surface Area of a Cone, ft^2 = (3.14)(Radius, ft) $\left(\text{Radius, ft}+\sqrt{(\text{Radius, ft})^2+(\text{Height, ft})^2}\right)$

Total Exterior Surface Area of a Cylinder, ft^2 =

$$\left(\text{end \#1 SA, ft}^2\right)+\left(\text{end \#2 SA, ft}^2\right)+[(3.14)(\text{Diameter, ft})(\text{Height, ft})]$$

Where SA = Surface Area of a Circle

Volume

Volume of a Cone*, ft^3 = (1/3)(0.785)$(\text{Diameter, ft})^2$(Height, ft)

Volume of a Cylinder*, ft^3 = (0.785)$(\text{Diameter, ft})^2$(Height, ft)

Volume of a Rectangular Tank*, ft^3 = (Length, ft)(Width, ft)(Height, ft)

Volume, gallons = $\left(\text{Volume, ft}^3\right)\left(7.48\ \text{gal/ft}^3\right)$

Velocity

Velocity, ft/sec = $\frac{\text{Distance, ft}}{\text{Time, sec}}$

Velocity, ft/sec = $\frac{\text{Flow Rate, ft}^3\text{/sec}}{\text{Area, ft}^2}$

*Pie Wheel Format for this equation is available at the end of this document

Flow

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

Flow Through a Channel, ft^3/sec = (Width, ft)(Depth, ft)(Velocity, ft/sec)

Flow Through a Full Pipeline, ft^3/sec = (0.785)(Diameter, ft)^2(Velocity, ft/sec)

Flow Through a Cone, ft^3/sec = (1/3)(0.785)(Diameter, ft)^2(Velocity, ft/sec)

Pounds (Feed Rate)

Mass*, lb = (Concentration, mg/L)(Volume, MG)(8.34 lb/gal)

$$\text{Mass, lb} = \frac{(\text{Concentration, mg/L})(\text{Volume, MG})(8.34\ \text{lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$$

Loading Rate*, lb/day = (Concentration, mg/L)(Flow, MGD)(8.34 lb/gal)

$$\text{Feed Rate, lb/day} = \frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34\ \text{lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$$

Dosage

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb/day})}{(\text{Flow, MGD})(8.34\ \text{lb/gal})}$$

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb/day})(\text{Chemical Purity, \% expressed as decimal})}{(\text{Flow, MGD})(8.34\ \text{lb/gal})}$$

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb})(\text{Chemical Purity, \% expressed as decimal})}{(\text{Volume, MG})(8.34\ \text{lb/gal})}$$

Solution Preparation

Three Normal Equation $(C_1 \times V_1)+(C_2 \times V_2)=(C_3 \times V_3)$

Two Normal Equation (Dilution) $(C_1 \times V_1)=(C_2 \times V_2)$

Where C = Concentration or Normality
and V = Volume
Units must be compatible

*Pie Wheel Format for this equation is available at the end of this document

Chemical Feeders

$$\text{Chemical Feed Pump Setting, \% stroke} = \frac{\text{Desired flow}}{\text{Maximum flow}} \times 100\%$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Flow, MGD})(\text{Dose, mg/L})(3.785\ \text{L/gal})(1{,}000{,}000\ \text{gal/MG})}{(\text{Chemical Density, mg/mL})(\text{Active Chemical, \% expressed as a decimal})(1440\ \text{min/day})}$$

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb/day})(\text{Chemical Purity, \% expressed as decimal})}{(\text{Flow, MGD})(8.34\ \text{lb/gal})}$$

$$\text{Feed Rate, lb/day} = \frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34\ \text{lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$$

$$\text{Solution Feeder Setting, gpd} = \frac{(\text{Dose, mg/L})(\text{Flow, MGD})(8.34\ \text{lb/gal})}{\text{Solution Concentration, lb/gal}}$$

$$\text{Specific Gravity} = \frac{\text{Density of substance, lb/gal}}{8.34\ \text{lb/gal}}$$

Distribution Systems Calculations

$$\text{Force*, lbs} = (\text{Pressure, psi})\left(\text{Area, in}^2\right)$$

$$\text{Leakage, gpd} = \frac{\text{Volume, gal}}{\text{Time, days}}$$

$$\text{Slope, \%} \frac{\text{Drop or Rise, ft}}{\text{Distance, ft}} = \times 100\%$$

$$\text{Water Use, gpcd} = \frac{\text{Volume of Water Produced, gpd}}{\text{Population Served, capita}}$$

Operations Calculations

$$\text{Water Flow from Hydrant, gpm} = (27)(\text{Nozzle ID, in})^2\left(\sqrt{\text{pitot pressure}}, \text{psig}\right)$$

$$\text{Meter Accuracy, \%} = \frac{\text{Volume of Water Registered, gal}}{\text{Actual Volume, gal}} \times 100\%$$

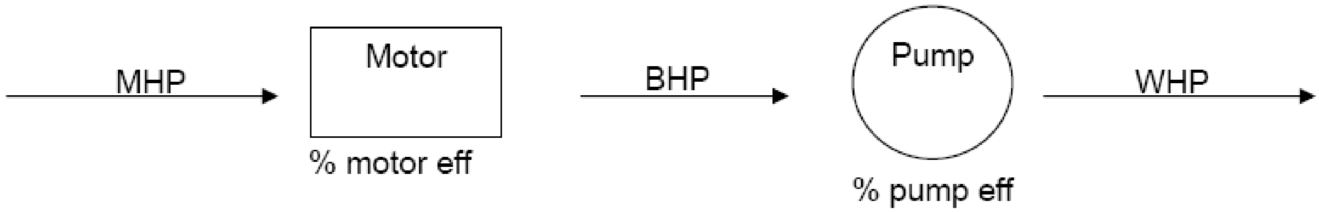
$$\text{Pressure, lb/ft}^2 = (62.4\ \text{lb/ft}^3)(\text{Water Column Height, ft})$$

$$\text{Uplift Force, lbs} = (62.4\ \text{lb/ft}^3)(\text{Volume, ft}^3)$$

$$\text{Leak Test Allowance, gal/hr} = \frac{(\text{Pipe Length, ft})(\text{Pipe Diameter, in})(\sqrt{\text{Average Test Pressure, psig}})}{148{,}000}$$

*Pie Wheel Format for this equation is available at the end of this document

Pumps and Motors



Horsepower

$$\text{Water Horsepower, hp} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)}$$

$$\text{Brake Horsepower, hp} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)(\text{Pump Efficiency, \% expressed as a decimal})}$$

$$\text{Brake Horsepower, hp} = \frac{\text{Water Horsepower, hp}}{\text{Pump Efficiency, \% expressed as a decimal}}$$

$$\text{Motor Horsepower, hp} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)(\text{Pump Efficiency, \% as a decimal})(\text{Motor Efficiency, \% as a decimal})}$$

$$\text{Motor Horsepower, hp} = \frac{\text{Water Horsepower, hp}}{(\text{Pump Efficiency,\% as a decimal})(\text{Motor Efficiency, \% as a decimal})}$$

$$\text{Motor Horsepower, hp} = \frac{\text{Brake Horsepower, hp}}{\text{Motor Efficiency, \% expressed as a decimal}}$$

Efficiency

$$\text{Efficiency, \%} = \frac{\text{Horsepower Output, hp}}{\text{Horsepower Supplied, hp}} \times 100\%$$

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

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

Wire-to-Water Efficiency, % =

$$(\text{Pump Efficiency, \% as a decimal})(\text{Motor Efficiency, \% as a decimal})(100\%)$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{Water Horsepower, hp}}{\text{Motor Horsepower, hp}} \times 100\%$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{(\text{Flow, gpm})(\text{Total Dynamic Head, ft})(0.746\ \text{kW/hp})}{(3{,}960)(\text{Electrical Demand, kW})} \times 100\%$$

Pumps and Motors (continued)

Pumping Rate

$$\text{Pumping Rate, gpm} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

$$\text{Pumping Rate of a Rectangular Tank, gpm} = \frac{(\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})\left(7.48\ \text{gal/ft}^3\right)}{\text{Time, min}}$$

$$\text{Pumping Rate of a Cylindrical Tank, gpm} = \frac{(0.785)(\text{Diameter, ft})^2(\text{Depth, ft})\left(7.48\ \text{gal/ft}^3\right)}{\text{Time, min}}$$

$$\text{Pumping Rate of a Conical Tank, gpm} = \frac{(1/3)(0.785)(\text{Diameter, ft})^2(\text{Depth, ft})\left(7.48\ \text{gal/ft}^3\right)}{\text{Time, min}}$$

$$\text{Time to Fill, min} = \frac{\text{Tank Volume, gal}}{\text{Flow Rate, gal/min}}$$

Power

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

$$\text{Amps (Single-Phase)} = \frac{(746\ \text{watts/HP})(\text{Horsepower})}{(\text{Volts})(\text{Efficiency,\% as a decimal})(\text{Power Factor})}$$

$$\text{Amps (Three-Phase)} = \frac{(746\ \text{watts/HP})(\text{Horsepower})}{(1.732)(\text{Volts})(\text{Efficiency,\% as a decimal})(\text{Power Factor})}$$

Electromotive Force*, volts = (Current, amps)(Resistance, ohms)

$$\text{Horsepower} = \frac{(\text{Volts})(\text{Amps})}{(746\ \text{watts/HP})}$$

Power, watts (AC Circuit) = (Volts)(Amps)(Power Factor)

Power, watts (DC Circuit) = (Volts)(Amps)

$$\text{Power Factor} = \frac{\text{Power, watts}}{(\text{EMF, volts})(\text{Amperage, amps})}$$

Cost, $/hour = (Motor Horsepower, hp)(0.746 kW/hp)(Cost, $/kW-hr)

*Pie Wheel Format for this equation is available at the end of this document

Chlorination

CT Calculation = (Disinfectant Residual Concentration, mg/L)(Time, min)

Chlorine Demand, mg/L = Chlorine Dose, mg/L – Chlorine Residual, mg/L

Chlorine Dose, mg/L = Chlorine Demand, mg/L + Chlorine Residual, mg/L

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb/day})(\text{Chemical Purity, \% expressed as a decimal})}{(\text{Flow, MGD})(8.34\ \text{lb/gal})}$$

$$\text{Feed Rate, lb/day} = \frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34\ \text{lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$$

$$\text{Hypochlorite Feed Rate, gpd} = \frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34\ \text{lb/gal})}{(\text{Chemical Purity,\% expressed as a decimal})(\text{Solution Density, lb/gal})}$$

$$\text{Bleach, gal (dilution)} = \frac{(\text{Desired Concentration, \% expressed as a decimal})(\text{Desired Volume, gal}}{\text{Available Chlorine from Bleach, \% expressed as a decimal}}$$

$$\text{HTH, lbs} = \frac{(\text{Desired Concentration, \% expressed as a decimal})(\text{Desired Volume, gal})(8.34\ \text{lb/gal})}{\text{Available Chlorine from HTH, \% expressed as a decimal}}$$

Laboratory Calculations

$$\text{Average (arithmetic mean)} = \frac{\text{Sum of All Terms}}{\text{Number of Terms}}$$

$$\text{Composite Sample Single Portion} = \frac{(\text{Instantaneous Flow})(\text{Total Sample Volume})}{(\text{Number of Portions})(\text{Average Flow})}$$

Temperature

$$\text{Temperature, °C} = \frac{(\text{°F} - 32)}{1.8}$$

Temperature, °F = (°C)(1.8) + 32

Well Formulas

$$\text{Well Yield, gal/min} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

Drawdown, ft = Pumping Water Level, ft – Static Water Level, ft

$$\text{Specific Capacity, gpm/ft} = \frac{\text{Well Yield, gal/min}}{\text{Drawdown, ft}}$$

Common Abbreviations

ac-ft = acre-feet
C = Celsius
cfs = cubic feet per second
cm = centimeters
DO = dissolved oxygen
Eff = efficiency
EMF = electromotive force
F = Fahrenheit
ft = feet
ft lb = foot-pound
g = grams
gal = gallons
gfd = gallons flux per day
gpcd = gallons per capita per day
gpd = gallons per day
gpg = grains per gallon
gpm = gallons per minute
hp = horsepower
hr = hours
in = inches
kg = kilograms
km = kilometers
kPa = kilopascals
kW = kilowatts
kWh = kilowatt-hours
lb = pounds
LSI = Langelier Saturation Index
m = meters
mg = milligrams
MG = million gallons
MGD = million gallons per day
min = minutes
mL = milliliters
ppb = parts per billion
ppm = parts per million
psi = pounds per square inch
Q = flow
RPM = revolutions per minute
SDI = sludge density index
sec = second
SS = settleable solids
TOC = total organic carbon
TSS = total suspended solids
W = watts
yd = yards
yr = year

Unit Conversion Factors

Linear

1 ft	= 0.305 m
1 ft	= 12 in
1 in	= 2.54 cm
1 yd	= 3 ft
1 mi	= 5,280 ft

Area

1 ac	= 43,560 ft^2
1 ac	= 0.405 Hectare
1 m^2	= 1.19 yd^2
1 ft^2	= 144 in^2
1 Hectare	= 2.47 ac
π or pi	= 3.14

Volume

1 ac-ft	= 43,560 ft^3
1 ac-ft	= 325,828.8 gal
1 ft^3	= 7.48 gal
1 L	= 0.2642 gal
1 L	= 1,000 mL
1 gal	= 231 in^3
1 gal	= 0.1337 ft^3
1 gal	= 3.785 L
1 MG	= 1,000,000 gal
1 m^3	= 264 gal
1 yd^3	= 27 ft^3

Flow

1 cfs	= 0.6463 MGD
1 cfs	= 448.8 gpm
1 MGD	= 694.44 gpm
1 MGD	= 1.55 cfs

Weight and Mass

1 ft^3 of water	= 62.4 lb
1 g	= 1,000 mg
1 gal of water	= 8.34 lb
1 kg	= 1,000 g
1 kg	= 2.2 lbs
1 lb	= 0.454 kg
1 lb	= 453.6 g
1 metric ton	= 2,205 lb
1 mg/L	= 0.0584 gpg
1 gpg	= 17.118 mg/L
1 ton	= 2,000 lb
1%	= 10,000 mg/L

Pressure and Head

1 atm	= 33.9 ft of water
1 atm	= 14.7 psi
1 ft of water	= 0.433 psi
1 psi	= 2.31 ft of water

Power

1 hp	= 0.746 kW
1 hp	= 746 W
1 hp	= 33,000 ft•lb/min
1 kW	= 1,000 W

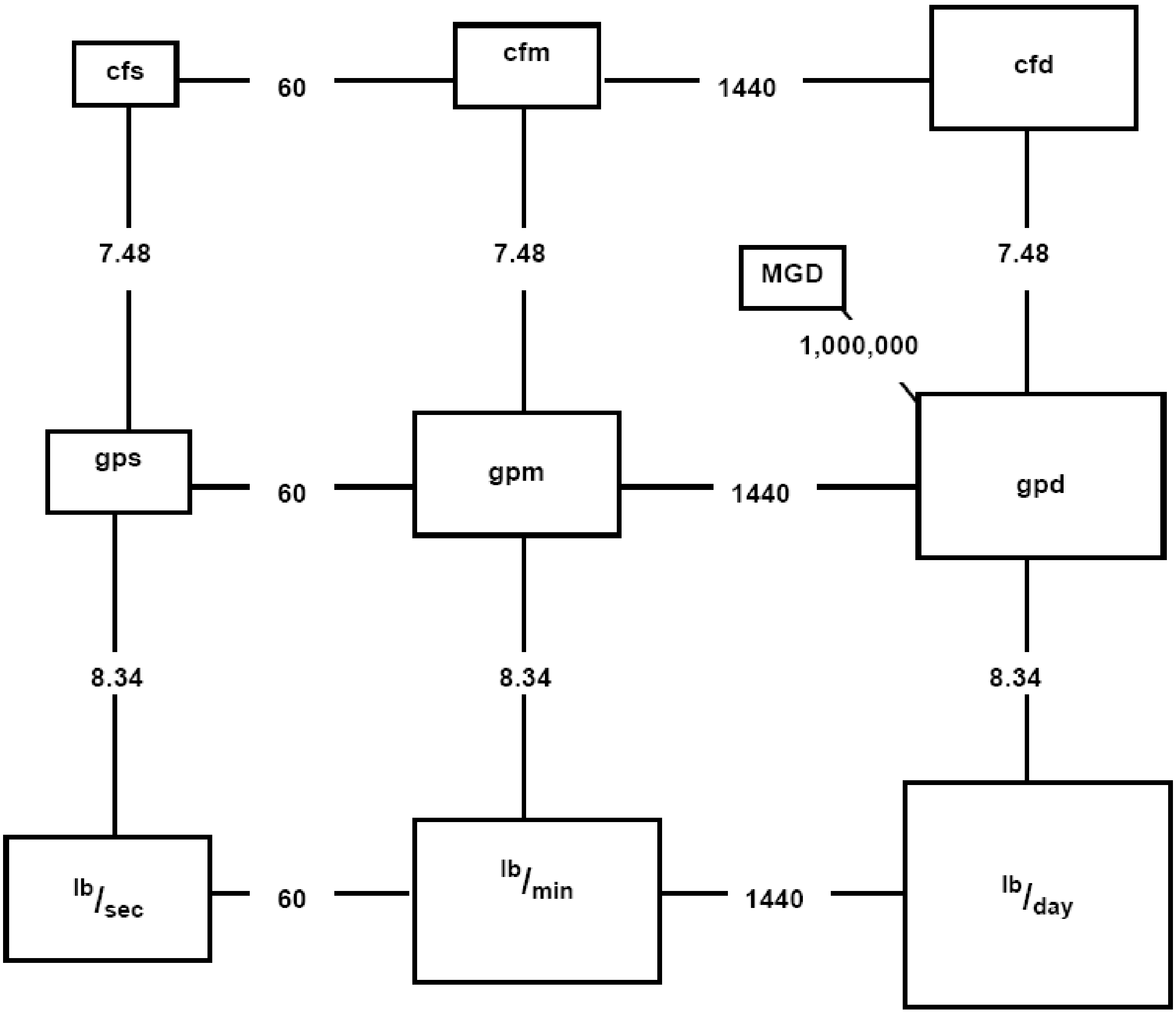
Metric Conversion Chart

Primary Unit

kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)
1,000	100	10	1	0.1	0.01	0.001

meter (m) - linear measurement
liter (L) - volume measurement
gram (g) - weight measurement

Flow Conversion Chart



To use this diagram: First, find the box that coincides with the beginning units (i.e. gpm). Then, find the box that coincides with the desired ending units (i.e. cfs). The numbers between the starting point and ending point are the conversion factors.

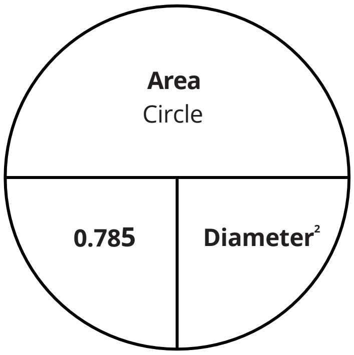
When moving from a **smaller box to a larger box, multiply** by the factor between them.

When moving from a **larger box to a smaller box, divide** by the factor between them.

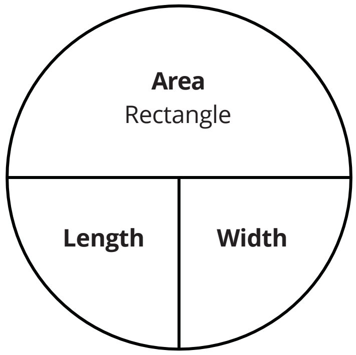
Pie Wheels

- To find the quantity above the horizontal line: multiply the pie wedges below the line together.
- To solve for one of the pie wedges below the horizontal line: cover that pie wedge, then divide the remaining pie wedge(s) into the quantity above the horizontal line.
- Given units must match the units shown in the pie wheel.
- When US and metric units or values differ, the metric is shown in parentheses, e.g. (m^2).

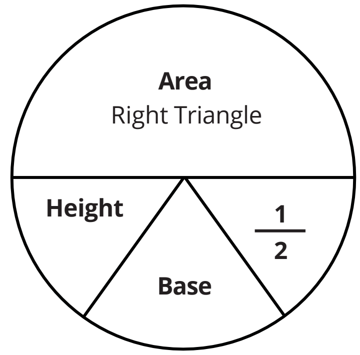
Area of Circle



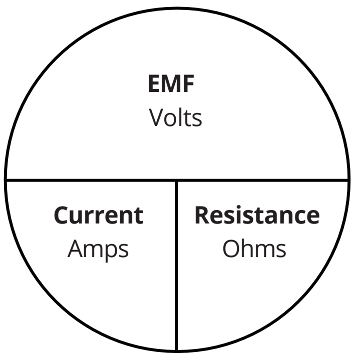
Area of Rectangle



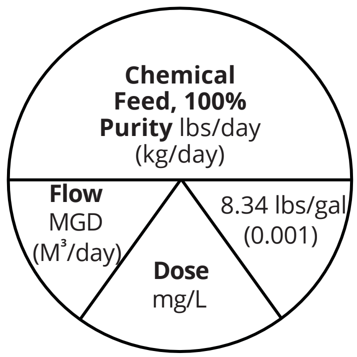
Area of Right Triangle



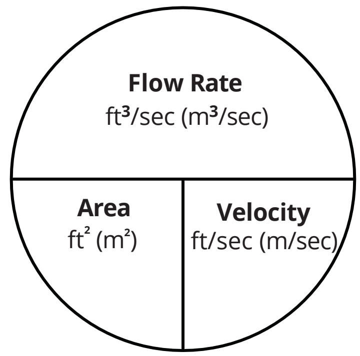
Electromotive Force (EMF), Volts



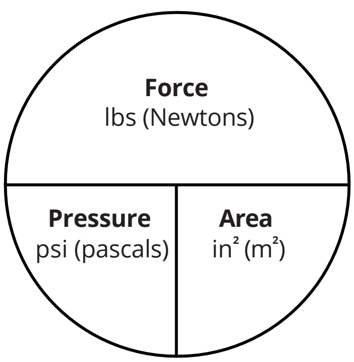
Feed Rate, lbs/day (kg/day)



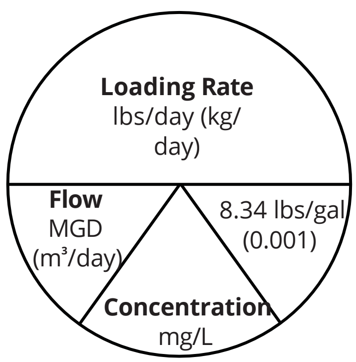
Flow Rate, ft^3/sec (m^3/sec)



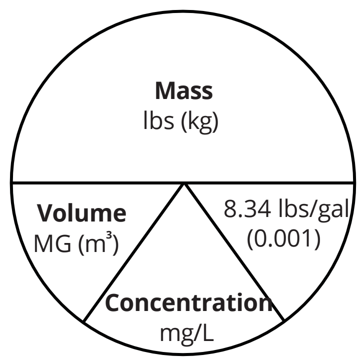
Force, lbs (Newtons)



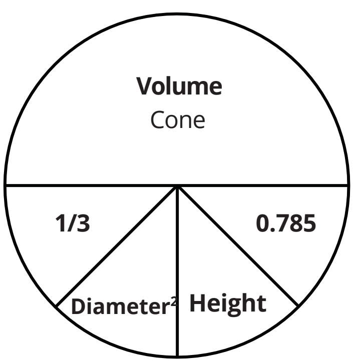
Loading Rate, lbs/day (kg/day)



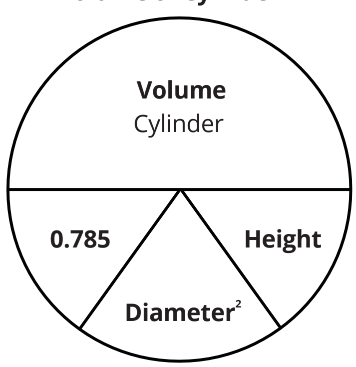
Mass, lbs (kg)



Volume of Cone



Volume of Cylinder



Volume of Rectangular Tank