State Water Resources Control Board

Operator Certification Examination—Equivalents and Formulas Sheet **(Revised Dec 2015)**

Equivalents

1 yd^3 = 27 ft^3	1 ft (water) = 0.43 psi
1 acre = 43,560 ft^2	1 psi = 2.31 ft (water)
1 ft^3 = 7.48 gal	1 yr = 365 d
1 gal (water) = 8.34 lb	1 d = 24 hr
1 L (water) = 1 kg	1 hr = 60 min
1 g = 1,000 mg	1 d = 1,440 min
1 kg = 1,000 g	1 hp = 550 ft·lb/s
1 L = 1,000 cm^3	1 hp = 0.746 kW
1 m^3 = 1,000 L	1 hp = 33,000 ft·lb/min
1 ml = 1 cm^3	1 hp = 3960 gpm·ft
1 ton = 2,000 lb	1 Mgal/d = 694 gal/min
1 mg/L = 1 ppm (water)	1 Mgal/d = 1.547 ft^3/s
1% (conc) = 10,000 mg/L	1 Mgal/d = 3.069 acre·ft/d

Units of Measure

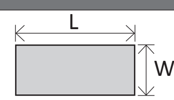
yd = yard	hr = hour
ft = foot	min = minute
gal = gallon	hp = horsepower
lb = pound	Mgal/d = MGD
L = liter	gal/min = gpm
g = gram	
kg = kilogram	
mg = milligram	
ml = milliliter	
psi = lb/in^2	
yr = year	
d = day	

Abbreviations [typical units]

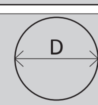
A = area [ft^2]
C = conc = concentration [mg/L]
Cl_{demand} = chlorine demand [mg/L]
Cl_{dosage} = chlorine dosage [mg/L]
$Cl_{residual}$ = chlorine residual [mg/L]
Q = flow rate [Mgal/d or MGD]
V = volume [gal]
v = velocity [ft/d]
VS_{in} = influent volatile solids
VS_{out} = effluent volatile solids

Perimeter (P)/Circumference (C)

Rectangle: P [ft] = 2L [ft] + 2W [ft]
where L = length and W = width



Circle: C [ft] = π × D [ft]
where π = constant = 3.1415; and D = diameter

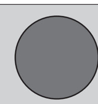


Area (A)

Rectangle: A [ft^2] = L [ft] × W [ft]
where L = Length and W = Width

Circle: where π = constant = 3.1415; D = diameter

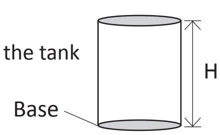
$$A\left[ft^2\right] = \frac{1}{4} \times \pi \times D^2 \left[ft^2\right]$$



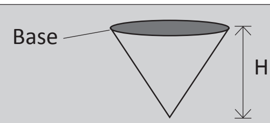
Volume (V)

Regular Prism: V [ft^3] = A_{base} [ft^2] × H [ft]

where A_{base} is the area of the base; and H is the height or depth of the tank



Cone: $$V\left[ft^3\right] = \frac{1}{3} A_{base}\left[ft^2\right] \times H\left[ft\right]$$



Detention Time or Hydraulic Retention Time (HRT)

$$HRT\left[hr\right] = \frac{V}{Q}$$ If Q is in $\left[\frac{gal}{d}\right]$ and V is in [ft^3], then detention time is

$$HRT = \frac{V\left[ft^3\right] \times \frac{7.48\,gal}{ft^3}}{Q\left[\frac{gal}{d}\right] \times \frac{d}{24\,hr}} = \frac{V\left[ft^3\right] \times \frac{7.48\,gal}{ft^3} \times \frac{24\,hr}{d}}{Q\left[\frac{gal}{d}\right]}$$

Acronyms [typical units]

AST = activated sludge tank
BOD = biochemical oxygen demand [mg/L]
DO = dissolved oxygen [mg/L]
DLR = digester loading rate
ET = evapotranspiration
F/M = food to microorganism ratio
HLR = hydraulic loading rate
hp = horsepower
HRT = hydraulic residence time or detention time [d]
kW = kilowatt
MCRT = mean cell residence time [d]
Mgal = million gallons
MLSS = mixed liquor suspended solids [mg/L]
MLVSS = mixed liquor volatile suspended solids [mg/L]
OLR = organic loading rate
RAS = return activated sludge
RBC = rotating biological contactor
RP = removal percentage
SS = suspended solids [mg/L]
TDH = $H_{dynamic}$ = total dynamic head [ft]
TF = trickling filter
VS = volatile solids
WAS = waste activated sludge
WOR = weir overflow rate
SLR = solids loading rate [lb/d]

Flow and Velocity

$$Q\left[\frac{ft^3}{d}\right] = v\left[\frac{ft}{d}\right] \times A\left[ft^2\right]$$

Removal Percentage (RP)

$$RP = \left(\frac{In - Out}{In}\right) \times 100$$

where In = influent concentration, Out = effluent concentration

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Hydraulic Loading Rate (HLR): typical units [gal/(d·ft²)]

$HLR = \frac{Q}{A}$, If Q$\left[\frac{gal}{d}\right]$ and A$\left[ft^2\right]$, then

$$HLR\left[\frac{gal}{ft^2 \cdot d}\right] = \frac{Q\left[\frac{gal}{d}\right]}{A\left[ft^2\right]}$$

or

$$HLR\left[\frac{ft}{d}\right] = \frac{Q\left[\frac{gal}{d}\right] \times \frac{ft^3}{7.48\,gal}}{A\left[ft^2\right]}$$

Note: If consistent units are used for flow rate and area, then the HLR is in units of length over time (ft/d).

Weir Overflow Rate (WOR): typical units [gal/(d·ft)]

Weir overflow rate is the flow rate per unit length of weir.

$$WOR\left[\frac{gal}{d \cdot ft}\right] = \frac{Q\left[\frac{gal}{d}\right]}{L\left[ft\right]}$$

where L = length of weir

Loading Rate: typical units [lb/d]

BOD or SS loading rate [lb/d] =

$$8.34\left[\frac{lb \cdot L}{Mgal \cdot mg}\right] \times Q\left[\frac{Mgal}{d}\right] \times C\left[\frac{mg}{L}\right]$$

Hydraulic Loading Rate (HLR): typical units [gal/d/ft²]

$$HLR\left[\frac{gal}{d \cdot ft^2}\right] = \frac{Q\left[\frac{gal}{d}\right]}{A\left[ft^2\right]}$$

Solids Loading Rate (SLR): typical units [lb/d/ft²]

$$SLR\left[\frac{lb}{d \cdot ft^2}\right] = \frac{Solids\ applied\left[\frac{lb}{d}\right]}{A\left[ft^2\right]}$$

Food to Microorganism Ratio (F/M): typical units $\left[\frac{\text{lb BOD}}{\text{lb VSS} \cdot \text{d}}\right]$

$$F/M\left[\frac{lb}{lb \cdot d}\right] = \frac{BOD\ applied\left[\frac{lb}{d}\right]}{MLVSS\left[lb\right]}$$

Return Activated Sludge (RAS) Flow Rate ($Q_{RAS\text{-}SS}$): typical units [Mgal/d or MGD]

$$Q_{RAS\text{-}SS}\left[\frac{Mgal}{d}\ or\ MGD\right] = \frac{Q\left[\frac{Mgal}{d}\right] \times MLSS_{tank}\left[\frac{mg}{L}\right] - Q_{WAS}\left[\frac{Mgal}{d}\right] \times SS_{RAS}\left[\frac{mg}{L}\right]}{SS_{RAS}\left[\frac{mg}{L}\right] - MLSS_{tank}\left[\frac{mg}{L}\right]}$$

Note: $SS_{RAS} = SS_{WAS}$

Mean Cell Residence Time (MCRT): typical units [d]

$$MCRT\left[d\right] = \frac{MLSS_{tank}\left[lb\right] + MLSS_{clarifier}\left[lb\right]}{SS_{effluent}\left[\frac{lb}{d}\right] + SS_{WAS}\left[\frac{lb}{d}\right]}$$

Waste Sludge Rate (SS_{WAS}): typical units [lb/d]

$$SS_{WAS}\left[\frac{lb}{d}\right] = \frac{MLSS_{tank}\left[lb\right] + MLSS_{clarifier}\left[lb\right]}{MCRT\left[d\right]} - SS_{effluent}\left[\frac{lb}{d}\right]$$

Sludge Volume Index (SVI): typical units [mL/g]

$$SVI\left[\frac{mL}{g}\right]=\frac{\text{Sludge Volume}\left[\frac{mL}{L}\right]\times 1{,}000\left[\frac{mg}{g}\right]}{MLSS\left[\frac{mg}{L}\right]}$$

The organic loading rate is the mass (lb) of organic (BOD) per unit area per day.
OR, it can be the mass (lb) of organic (BOD) per unit volume per day.

Organic loading rate = $OLR_{Area} = \frac{Q\times BOD}{A}$

where Q = flow rate, BOD = concentration of BOD, and
A = surface area of the treatment system (for example, RBC or ponds)

Organic loading rate = $OLR_{Volume} = \frac{Q\times BOD}{V}$

where Q = flow rate, BOD = concentration of BOD, and
V = volume of treatment system (typically applies to trickling filters)

For Rotating Biological Contactor (RBC)
The organic loading rate is expressed per 1,000 ft^2 of area.

$$OLR_{RBC}=\frac{Q\times BOD}{A}$$

$$OLR_{RBC}\left[\frac{lbBOD}{1000\,ft^2\cdot d}\right]=\frac{Q\left[\frac{Mgal}{d}\right]\times BOD\left[\frac{mg}{L}\right]\times 8.34\left[\frac{L\cdot lb}{Mgal\cdot mg}\right]}{A\left[ft^2\right]\times\frac{1}{1{,}000\,ft^2}}$$

For Trickling Filters (TF)
The organic loading rate is expressed per 1,000 ft^3 volume of the filter:

$$OLR_{Volume}\left[\frac{lbBOD}{1000\,ft^3\cdot d}\right]=\frac{Q\left[\frac{Mgal}{d}\right]\times BOD\left[\frac{mg}{L}\right]\times 8.34\left[\frac{L\cdot lb}{Mgal\cdot mg}\right]}{V\left[ft^3\right]\times\frac{1}{1{,}000\,ft^3}}$$

For Ponds
The organic loading rate is expressed per unit area in acres:

$$OLR_{Area}\left[\frac{lbBOD}{Area\cdot d}\right]=\frac{Q\left[\frac{Mgal}{d}\right]\times BOD\left[\frac{mg}{L}\right]\times 8.34\left[\frac{L\cdot lb}{Mgal\cdot mg}\right]}{A\left[acre\right]}$$

Pump Efficiency (E_{pump}): typical units [%]

$$E_{pump}[\%] = \frac{HP_{water}}{HP_{brake}} \times 100$$

Brake Power (P_{Brake}): typical units [hp]

$$P_{Brake} = P_{motor} \times E_{motor}$$

where P_{brake} = brake power, P_{motor} = motor power, and E_{motor} = motor efficiency

If the water power is given in kW, the brake power can be expressed in horsepower using the following equation:

$$P_{Brake\ HP}[hp] = P_{motor}[kW] \times \frac{[hp]}{0.746[kW]} \times E_{motor}$$

Water Power (P_{water})

$P_{water} = Q \times H_{dynamic}$; where P_{water} = water power, Q = flow rate, and $H_{dynamic}$ = total dynamic head

If horsepower is desired as a unit for water power, with gal/min (gpm) for flow rate and feet for total dynamic head, then

$$P_{water\ HP}[hp] = Q\left[\frac{gal}{\min}\right] \times H_{dynamic}[ft] \times \left[\frac{ft^3}{7.48gal}\right] \times \left[62.4\frac{lb}{ft^3}\right] \times \frac{HP}{33,000\left[\frac{lb \cdot ft}{\min}\right]}$$

$$P_{water\ HP}[hp] = Q\left[\frac{gal}{\min}\right] \times H_{dynamic}[ft] \times \frac{1}{3,960}\left[\frac{HP}{gal/\min \cdot ft}\right]$$

Percent Volatile Solids Reduction ($\%VS_{reduction}$): typical units [%]

$$\%VS_{reduction}[\%] = \frac{VS_{in} - VS_{out}}{VS_{in} - (VS_{in} \times VS_{out})} \times 100$$

Chlorine Demand (Cl_{demand}): typical units [mg/L]

$$Cl_{demand}\left[\frac{mg}{L}\right] = Cl_{dosage}\left[\frac{mg}{L}\right] - Cl_{residual}\left[\frac{mg}{L}\right]$$

BOD Test – Estimation of BOD Value

$$BOD\left[\frac{mg}{L}\right] = \frac{DO_{initial}\left[\frac{mg}{L}\right] - DO_{final}\left[\frac{mg}{L}\right]}{\frac{V_{sample}[mL]}{V_{bottle}[mL]}}$$

Pond Hydraulic Loading Rate (HLR_{pond}): typical units [in/d]

$$HLR_{pond}\left[\frac{in}{d}\right] = \frac{d_{pond}[in]}{HRT_{pond}[d]}$$

Pond Hydraulic Balance

$$Q_{in}\left[\frac{in}{d}\right] - Q_{out}\left[\frac{in}{d}\right] = Q_{pond}\left[\frac{in}{d}\right] + Q_{rain}\left[\frac{in}{d}\right] - Q_{ET}\left[\frac{in}{d}\right]$$