Basic and Practical Water Treatment Math

Presented by
R. Trace Blackmore, CWT, LEED AP
Blackmore Enterprises, Inc.
Atlanta, Georgia

AWT Training Seminars

ASSOCIATION OF WATER TECHNOLOGIES

Top 10 Phobias

Google

1. **Acrophobia -** Fear of Heights
2. **Claustrophobia -** Fear of Enclosed Spaces
3. **Nyctophobia -** Fear of the Dark
4. **Ophidiophobia -** Fear of Snakes
5. **Arachnophobia -** Fear of Spiders
6. **Trypanophobia -** Fear of Injection or Medical Needles
7. **Astraphobia -** Fear of Thunder and Lightning
8. **Nosophobia -** Fear of Having a Disease
9. **Mysophobia AKA Germophobia -** Fear of Germs
10. **Triskaidekaphobia -** Fear of the Number 13

BASIC MATH REVIEW

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The Language of Math

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Order of Operations

Parentheses → Exponents → Multiply → Divide → Add → Subtract

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How to Use the Order of Operations

PEMDAS

$2 + 3^2(5 - 1) = ?$

- Add 5 + -1 in the parenthesis to get 4.

$2 + 3^2(4) = ?$

- Raise the 3 to the second power to get 9.

$2 + 9(4) = ?$

- Multiply the 9 and 4 to get 36.

$2 + 36 = ?$

- Add 2 and 36.

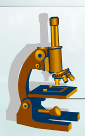
Your final answer is 38.

Volume Formulas

- cube = a^3
- rectangular prism = $a \cdot b \cdot c$
- irregular prism = $b \cdot h$
- cylinder = $\Pi r^2 h$
- pyramid = $(1/3)\, b \cdot h$
- cone = $1/3\, \Pi r^2 h$
- sphere = $(4/3)\, \Pi r^3$
- ellipsoid = $(4/3)\, \Pi r_1 r_2 r_3$

$\Pi = 3.141592$

SI Notation



Prefix	Symbol	1000^m	10^n	Decimal	Short scale	Long scale
yotta	Y	1000^8	10^{24}	1 000 000 000 000 000 000 000 000	Septillion	Quadrillion
zetta	Z	1000^7	10^{21}	1 000 000 000 000 000 000 000	Sextillion	Trilliard
exa	E	1000^6	10^{18}	1 000 000 000 000 000 000	Quintillion	Trillion
peta	P	1000^5	10^{15}	1 000 000 000 000 000	Quadrillion	Billiard
tera	T	1000^4	10^{12}	1 000 000 000 000	Trillion	Billion
giga	G	1000^3	10^9	1 000 000 000	Billion	Milliard
mega	M	1000^2	10^6	1 000 000	Million	
kilo	k	1000^1	10^3	1 000	Thousand	
hecto	h	$1000^{2/3}$	10^2	100	Hundred	
deca	da	$1000^{1/3}$	10^1	10	Ten	
		1000^0	10^0	1	One	
deci	d	$1000^{-1/3}$	10^{-1}	0.1	Tenth	
centi	c	$1000^{-2/3}$	10^{-2}	0.01	Hundredth	
milli	m	1000^{-1}	10^{-3}	0.001	Thousandth	
micro	µ	1000^{-2}	10^{-6}	0.000 001	Millionth	
nano	n	1000^{-3}	10^{-9}	0.000 000 001	Billionth	Milliardth
pico	p	1000^{-4}	10^{-12}	0.000 000 000 001	Trillionth	Billionth
femto	f	1000^{-5}	10^{-15}	0.000 000 000 000 001	Quadrillionth	Billiardth
atto	a	1000^{-6}	10^{-18}	0.000 000 000 000 000 001	Quintillionth	Trillionth
zepto	z	1000^{-7}	10^{-21}	0.000 000 000 000 000 000 001	Sextillionth	Trilliardth
yocto	y	1000^{-8}	10^{-24}	0.000 000 000 000 000 000 000 001	Septillionth	Quadrillionth

Algebra Review

$$2x + 4 = 6$$
$$-4 = -4$$

$$2x = 2$$
$$\frac{2x}{2} = \frac{2}{2}$$
$$x = 1$$

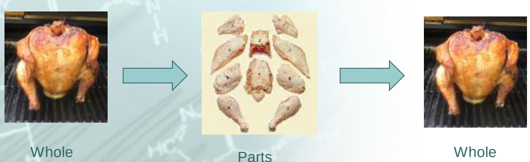
$$2(1) + 4 = 6$$

Presentation Download

http://www.awt.org/tt/tt_2013.cfm

- Latest Presentation
- Algebra Review
- Conversion Tables

Approach Method



What is the next letter?

O,T,T,F,F,S,S E ?

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Cast of Characters

- All equations are based on:
  - Physics and Chemistry
  - Theory
  - Referenced in AWT's Technical Reference and Training Manual (TRTM)
    - Used on CWT Exam
  - Assumptions
    - "Rules of Thumb"

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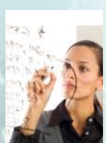
The ONLY Rule for This Session

Math is NOT a Spectator sport.

- You MUST work every problem.



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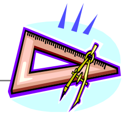
Conversion Factors



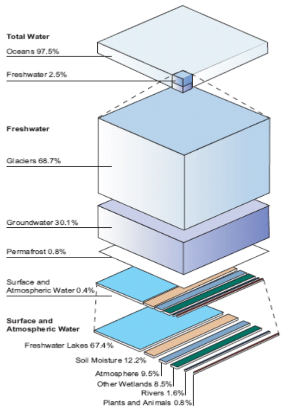
Remember: Like Terms!

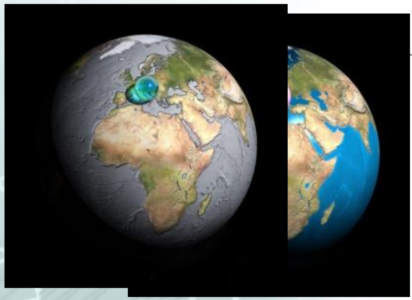
- 1′ = 12″
- 1″ = 2.54 cm
- 1^{2}′ = 144^{2}″
- 1^{3}′ = $1{,}728^{3}$″
- 1 pint = 2 cups
- 1,000 ml = 1 liter
- 1 gl. = 4 qt.
- 1 gl. = 3.785 liters
- 1 lb. = 16 oz.
- 1 ton = 2,000 lbs.
- 1 oz. = 28.35 grams

Garbage In = Garbage Out

Water

- A clear, colorless, odorless, and tasteless liquid, H_2O, essential for most plant and animal life and the most widely used of all solvents.
  - Properties of Water:
    - **Freezes @ 32 °F (0 °C)**
    - **Boils @ 212 °F (100 °C)**
    - **Specific gravity= 1.0**
    - **8.345 lbs/gal**
    - **7.48 gal/ft³**
    - **Ft³ = 62.43 lbs.**



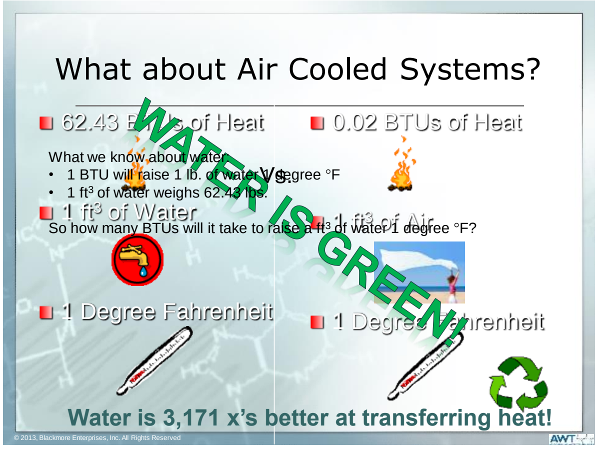


Why Do We Use Water ?

- 1 BTU (Heat)
- 1 Pound of Water
- 1 Degree (°F)

Vs.

- 1 BTU (Heat)
- 1 Pound of Steel
- 10 Degrees (°F)


What about Air Cooled Systems?
62.43 B s of Heat
0.02 BTUs of Heat
What we know about water:
• 1 BTU will raise 1 lb. of water 1 degree °F
• 1 ft³ of water weighs 62.43 lbs.
Vs.
1 ft³ of Water
1 ft³ of Air
So how many BTUs will it take to raise a ft³ of water 1 degree °F?
WATER IS GREEN!
1 Degree Fahrenheit
1 Degre ahrenheit
Water is 3,171 x's better at transferring heat!
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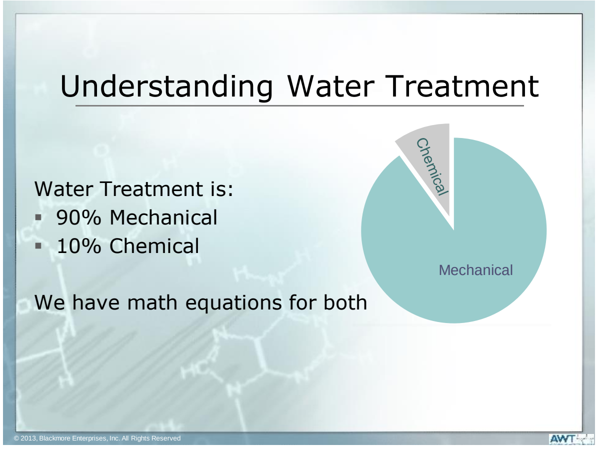
Understanding Water Treatment
Water Treatment is:
▪ 90% Mechanical
▪ 10% Chemical
We have math equations for both
Chemical
Mechanical
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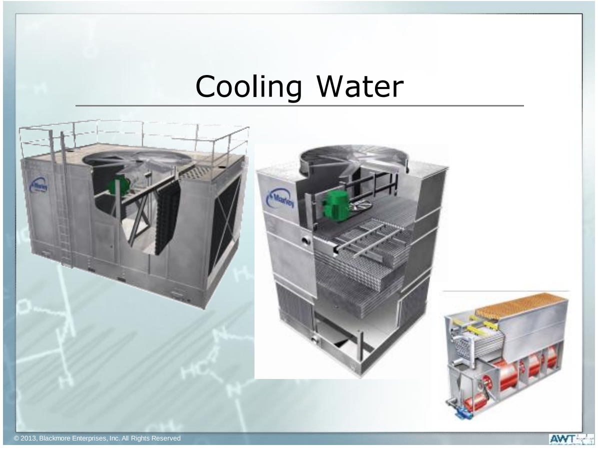
Cooling Water
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Cooling Water Calculations

In order for us to calculate the cooling water equations, we need certain information:

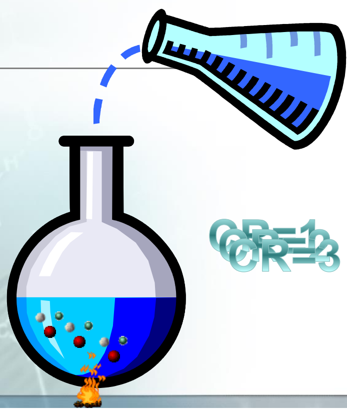
- General Survey
  - Cooling system type
  - System design
  - Hours of operation
  - Loading
  - Water quality
  - System volume
- Technical data
  - Product data
    - Dosage rates (ppm)
    - Product limits
    - Contact time
    - Product pricing
  - Goals for program
  - Etc…

Concentration Ratio

Concentration ratio is the name given to the artist previously known as "Cycles of Concentration".

Concentration Ratio = Cycles of Concentration

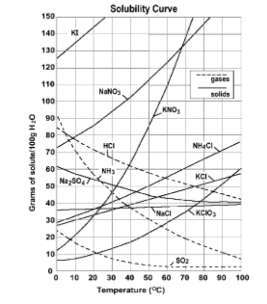
"CR"



Question?

- So why can't we indefinitely concentrate the water to decrease waste?

Concentrating Compounds



Georgia Sweet Tea

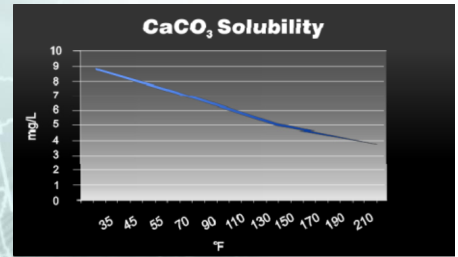
Regular Sweet Tea

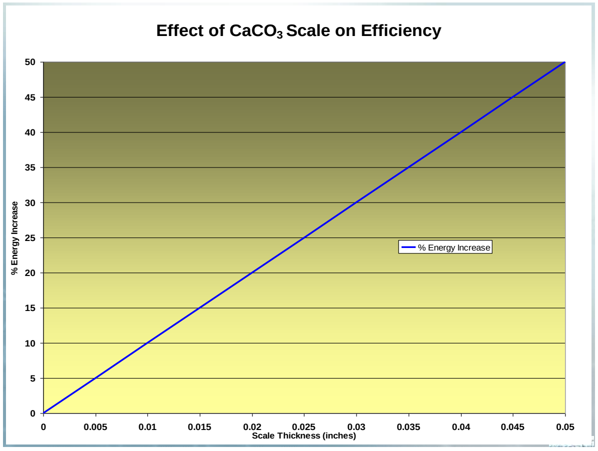
Nutrition Facts	
Serving Size (83g)	
Servings Per Container	
Amount Per Serving	
Calories 280	Calories from Fat 180
	% Daily Value*
Total Fat 21g	32%
Saturated Fat 13g	65%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 115mg	5%
Total Carbohydrate 25g	8%
Dietary Fiber 4g	16%
Sugars 19g	
Protein 2g	

Georgia Sweet Tea

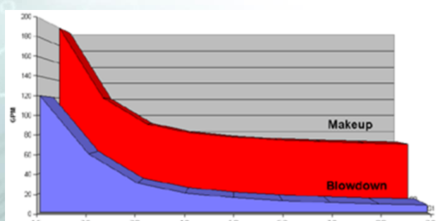
Nutrition Facts	
Serving Size (83g)	
Servings Per Container	
Amount Per Serving	
Calories Don't Ask	Calories from Fat 180
	% Daily Value*
Total Fat 21g	32%
Saturated Fat 13g	65%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 115mg	5%
Total Carbohydrate 404g	128%
Dietary Fiber 4g	16%
Sugars 400g	
Protein 2g	

Concentrating Too Much



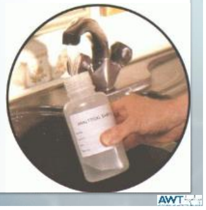


Not Concentrating Enough



Calculating the Maximum Concentration Ratio

- Maximum Concentrations for "AWT-X410"
  - Silica
  - Alkalinity
  - Hardness
    - Check product specifications

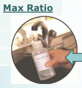


Calculating the Maximum Concentration Ratio

- Limiting factors

$$\frac{Maximum\ Concentration\ ppm}{Makeup\ Water\ ppm} = Maximum\ Ratio$$

Substituent	Limit	Raw	Max Ratio
Silica	150	12	
Alkalinity	600	50	
Hardness	1000	95	



- The lowest number is your limiting factor

Concentration Ratio

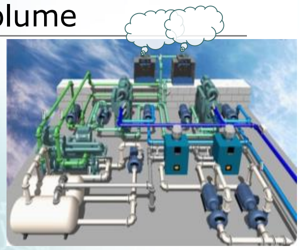
$$\frac{Tower\ Cond.}{Makeup\ Cond.} = Concentration\ Ratio$$

$$\frac{800}{120} = ?$$

$$\frac{Tower\ Cl^-}{Makeup\ Cl^-} = Concentration\ Ratio$$

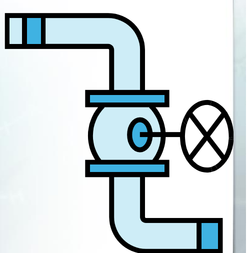
$$\frac{165}{20} = ?$$

Volume



- How much do I use?
  - How big is the system?
- System volume
  - Determined by:
    - Compound addition
    - Water piping and holding area determination
- Makeup volume
  - Determined by:
    - Mass balance equation

Estimating Volume in System

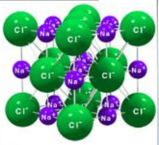


- Estimating volume:
  - $(Ft^3_B \times 7.48) + PG$
- Definitions:
  - Ft^3_B = Cubic feet of tower basin
  - PG = Gallons in linear feet of pipe
    - $\Pi r^2 L' \times 7.48$

Compound Addition

- If we add a known weight of any non-scaling compound, we can calculate the volume once that compound is totally dispersed throughout the system.
- Most common in cooling tower is sodium chloride (NaCl)
  - Also commonly used compounds:
    - Moly
    - Nitrite

Compound Addition (salt sizing)



- Estimate the system size based on:
  - Piping
  - Sump dimensions
  - * add 0.5 - 1 lb. of salt per 1000 estimated gallons.

$$\frac{120{,}000\ x\ NaCl_{\#}}{(Cl_f - Cli)\ 1.65}$$

  - Definitions:
    - $NaCl_{\#}$ = Lbs. of salt added to the system
    - Cl^-_f = Final chloride result
    - Cl^-_i = Initial chloride result

- 1.65 is the conversion factor to convert lbs. of NaCl added to Cl^- tested

Why 120,000?

- 1 lb. of any substance in 1000 gallons of water will yield 120 ppm of that substance.
- Let's prove this:
  - Water weighs 8.345 lbs. per gallon
    - So, 1000 gallons of water weighs 8,345 lbs.
- So let's put 1 pound of substance "X" in 1000 gal. (8,345 lbs.) of water.
  - Now let's convert that to pounds per million:

$$1\ x\ \frac{1{,}000{,}000}{8{,}345} = 119.8$$

Let's call it an even 120

$$\text{x 1000}\ \frac{1\ lb.}{1000 gal} = 120 ppm\ \text{x 1000}$$

1 (lb) = 120,000 (ppm/gal)

Other Compound Addition Equations

- Salt: $\frac{120{,}000\ x\ NaCl_{\#}}{(Cl^-{}_f - Cl^-{}_i)\ 1.65}$ $\frac{73{,}229\ x\ NaCl_{\#}}{(Cl^-{}_f - Cl^-{}_i)}$
- Nitrite: $\frac{120{,}000\ x\ NaNO_{2_{\#}}}{(NaNO_{2_f} - NaNO_{2_i})}$
- Molybdate: $\frac{120{,}000\ x\ Na^2MoO_{4_{\#}}}{(MoO_4 f - MoO_4 i)\ 1.28}$ $\frac{93{,}750\ xNa^2MoO_{4_{\#}}}{(MoO_4 f - MoO_4 i)}$

Where do these conversion factors come from?

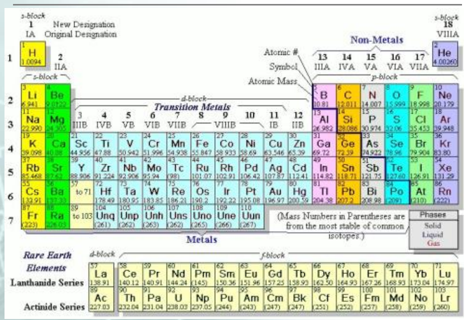
- Sodium molybdate (Na_2MoO_4) to molybdate (MoO_4)

mw=205.92 *mw*=159.94

$$\frac{What\ we\ add}{What\ we\ test} = F'$$

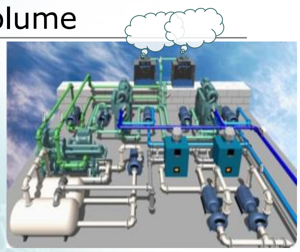
$$\frac{205.92}{159.94} = 1.28$$

Knock Yourself Out!



Volume

- System volume
- Makeup volume



Evaporation Rate

$$E = 0.001 \times RR \times \Delta T \times F'$$

- Definitions:
  - E = Evaporation
  - RR = Recirculation Rate (tonnage x 3)
  - ΔT = Temperature differential across tower
  - F' = Sensible loss of heat (0.8 – 0.9)

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0.001?

- It takes ±1,000 (970) BTU's to evaporate 1 lb. of water

$$\frac{1\ lb}{1{,}000\ BTU} = 0.001$$

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Evaporation Rate

$$E = 0.001 \times RR \times \Delta T \times F'$$

- Definitions:
  - E = Evaporation
  - RR = Recirculation Rate (tonnage x 3)
  - ΔT = Temperature differential across tower
  - F' = Sensible loss of heat (0.8 – 0.9)

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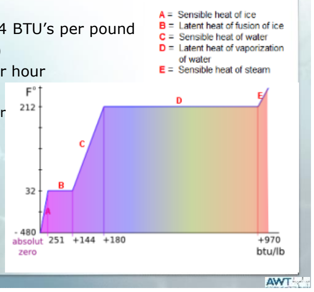
Why a Ton?

- Latent heat of fusion of ice is 144 BTU's per pound
- 2000 lbs. x (144 btu's/24 hours)
- 12,000 btu's per ton of water per hour
- A chiller ton removes 12,000 btu's/hr



Tonnage x's 3?

- What we know:
  - A chiller removes 12,000 BTU's per hour per ton
  - A tower is sized to remove the chillers 12,000 btu's plus 3,000 btu's for the chiller's parasitic heat.
    - A tower ton is 15,000 BTU's/hour
- Let's do another proof:
  - Water weighs 8.345 lbs. per gallon
    - Flow rate is in Minutes, but tonnage is based on Hours
- Flow rate using pounds per hour:
    - 8.345 x 60 = 500.7
      - So, 500.7 is our flow constant per 1 degree Fahrenheit.
  - Towers are usually designed at a 10° ΔT, so, 500.7 x 10 = 5007
- Now let's put them together:
  - 15,000 / 5007 = ±3

Factors for Non-HVAC

- Absorption chillers:
  - Tonnage x's 4*
- Others:
  - Use actual recirculation rate
    - ±10 GPM of evaporation per 1,000 GPM of flow @ 10°F ΔT

*30,000 BTU's at ΔT 15°F

$E = 0.001 \times RR \times \Delta T \times F'$

E = 1.8 Gallons per Ton?

$$15{,}000\ BTU's \quad \times \quad \frac{1\ lb.}{1000\ BTUs} \quad \times \quad \frac{1\ Gal.}{8.345\ lb/gal}$$

How many BTU's in a tower Ton?

How Many BTU's to evaporate 1 lb. of water?

How much does a gallon of water weigh?

=1.8

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Blowdown

$$B = \frac{E}{CR - 1} \qquad B = \frac{1}{CR \times MU}$$

"The solution to pollution is dilution"

- Definitions:
  - B = Bleed, controlled or uncontrolled
  - E = Evaporation
  - CR = Concentration ratio
  - MU = Makeup in gallons

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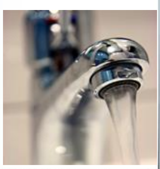
Makeup

$$E + B = MU \qquad MU = \frac{E \times CR}{CR - 1}$$

- Definitions
  - E = Evaporation
  - B = Bleed, controller or uncontrolled
  - CR = Concentration ratio
  - MU = Makeup



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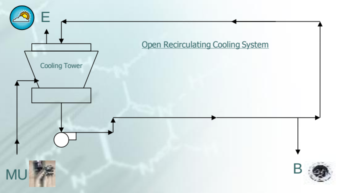
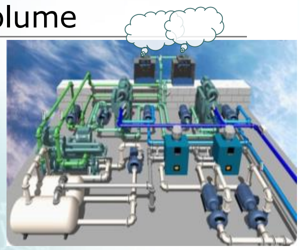
Mass Balance

$E = 0.001 \times RR \times \Delta T \times F'$ $\quad B = \frac{E}{CR - 1}$ $\quad E + B = MU$

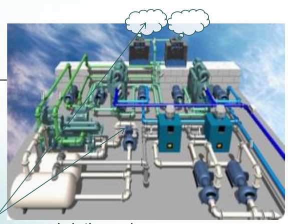


Volume



- System volume
- Makeup volume

Feed Rates



- Now that we have a system volume and daily makeup rate, we can begin to calculate dosages for our products.
- We have two methods to consider and calculate:
  - Entire system dose (slug)
    - To treat the entire system volume up to the recommended product ppm
  - Maintenance dose
    - To maintain the recommended product ppm

Volume
~~Slug~~ Feed

$$\frac{V \times ppm}{120{,}000} = lbs.\,of\ product\ needed$$

- Definitions:
  - V = System volume
  - ppm = ppm of product needed

Maintenance Feed

$$\frac{MU \times ppm}{120{,}000 \times CR} = lbs.\,of\ product\ needed$$

- Definitions:
  - MU = System makeup
  - ppm = ppm of product needed
  - CR = Concentration Ratio

NOW IT'S YOUR TURN!

give it a go

Surveying a new system

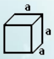
- System data (what we get from the survey)
  - 1- 250 ton tower
  - GPM ???
  - $\Delta T = 10^{\circ}F$
  - Operates 14 hr/day
  - Maximum concentration ratio: 5
- Note potential problems
  - Dead legs
  - Idle equipment
  - Low flow
  - Skin Temperatures
  - Contamination sources
- Now we need to calculate the rest!
  - System volume
  - Mass balance

Tonnage x's 3

Example, system volume

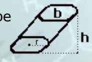
Why 7.48?

- We "walked" the system and found the following:
  - Tower basin: 12'x15'x1.5'
    - L' x W' x H' x 7.48



270 x 7.48= 2,020 *gal.*

  - Pipe: 1200' of 4" pipe
    - $\Pi r^2 L' \times 7.48$



$\frac{4"}{12"} = 0.33'$, $\frac{0.33'}{2} = 0.167'$

3.14 x (0.167 x 0.167) x 1,200

3.14 x 0.028 x 1,200 = 105.5

105.5 x 7.48 = 789 gal.

2,020 + 789 = 2,809 estimated gallons in system

Example, Compound Addition

- Compound Addition:
  - Salt $\frac{120{,}000\ x\ NaCl_{\#}}{(Cl^{-}_{f} - Cl^{-}_{i})\ 1.65}$
  - Estimated volume: 2,800 gallons
    - Salt added: 2 lbs.
    - Initial Cl^- reading: 120 ppm
    - Final Cl^- reading: 180 ppm

$$\frac{120{,}000\ x\ 2}{(180-120)\ 1.65} = 2{,}424 \text{ gallons}$$

What did this procedure save us?

estimation salt

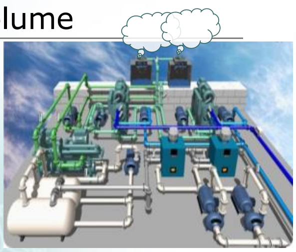
- 2,809 – 2,424 =

385 gallons

A 200 ppm biocide will be overfed 0.64 lbs. per dose
If fed daily, over a year's time that is **an extra 235 lbs.**

Volume

- System volume
- Makeup volume



Example, Mass Balance

$E = 0.001 \times RR \times \Delta T \times F'$ $B = \frac{E}{CR - 1}$ $E + B = MU$

- System data:
  - 1- 250 ton tower
  - 1- 750 gpm condenser pump
  - $\Delta T = 10^{\circ}F$
  - Operates 14 hr/day
  - Factor = 0.8

$E = 0.001 \times 750 \times 10 \times 0.8$

$E = 6\ gpm$

$(6.0)(840) = 5{,}040\ gpd$

Loading Factor

Example, Mass Balance

$E = 5{,}040\ gpd$ $\quad B = \frac{E}{CR - 1}$ $\quad E + B = MU$

- System data:
  - 1- 250 ton tower
  - 1- 750 gpm condenser pump
  - ΔT = 10˚F
  - Operates 14 hr/day
  - Maximum concentration ratio: 5

$$B = \frac{5{,}040}{5 - 1} = 1{,}260\ gpd$$

Example, Mass Balance

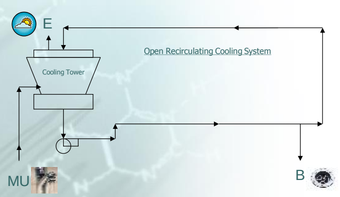
$E = 5{,}040\ gpd$ $\quad B = 1{,}260$ $\quad E + B = MU$

- System data:
  - 1- 250 ton chiller
  - 1- 750 gpm condenser pump
  - ΔT = 10˚F
  - Operates 14 hr/day
  - Maximum concentration ratio: 5

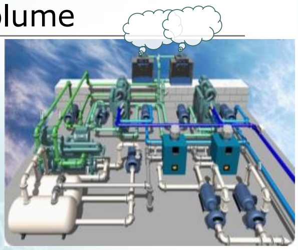
$$5{,}040 + 1{,}260 = 6{,}300\ gpd$$

Mass Balance

$E = 5040$ $\quad B = 1{,}260$ $\quad Mu = 6{,}300$



Volume



- System volume
- Makeup volume

Example, Product Dosing (S~~y~~g) *(Volume)*

$$\frac{V \times ppm}{120{,}000} = lbs.\,of\ product\ needed$$

- System data:
  - System volume
    - 2,424 gallons
- Product data:
  - "X410"
    - Dosage rate: 100 ppm
    - Specific gravity: 1.13

$$\frac{2{,}424 \times 100}{120{,}000} = 2.02\ lbs.\,of\ X410$$

$$SG\ x\ H_2O_{\#} = product\ weight\ per\ gal.$$

1.13 x 8.345 = 9.43 lbs. per gallon

$$\frac{Product\ lbs\ needed}{Product\ lbs.\,per\ gallon} = gallons\ of\ product$$

$$\frac{2.02}{9.43} = 0.21\ gallons\ X410$$

$$0.21 * 128 = 27\ oz$$

Example, Product Dosing (Maintenance)

$$\frac{MU \times ppm}{120{,}000 \times CR} = lbs.\,of\ product\ needed$$

- System data:
  - GPD Makeup
    - 6,300 gallons
  - Concentration ratio
    - 5
- Product data:
  - "X410"
    - Dosage rate: 100 ppm
    - Specific gravity: 1.13

$$\frac{6{,}300 \times 100}{120{,}000 \times 5} = 1.05\ lbs.\,of\ X410$$

$$SG\ x\ H_2O_{\#} = product\ weight\ per\ gal.$$

1.13 x 8.345 = 9.43 lbs. per gallon

$$\frac{Product\ lbs\ needed}{Product\ lbs.\,per\ gallon} = gallons\ of\ product$$

$$\frac{1.05}{9.43} = 0.11\ gallons\ X410$$

$$0.11 * 128 = 14.08\ oz$$

Pump Settings

- We added 27 oz. of "X410" to the system to achieve a 100 ppm concentration in the bulk water.
- Now we need to maintain the 100 ppm concentration of "X410."
  - 14 oz. Daily
  - Equipment:
    - 14.4 gpd pump
    - Controller set on percentage time

Like Terms

- Our pump is rated in GPD and we calculated our dosage in Ounces???
- First, we need to convert a 14.4 GPD pump output into something we can use (ounces)

Gallons per day
↓ Gallons per hour
↓ Gallons per minute
↓ Ounces per minute

- 14.4 gpd / 24 hrs = 0.6 gph
- 0.6 / 60 = .01 gpm
- 0.01 x 128 = 1.28 ounces per minute

Pump Setting, Con'd

- Pump Output:
  - 1.28 ounces per minute @ 100%
  - 0.64 opm @ 50%
  - 0.32 opm @ 25%
  - 0.128 opm @10%...
- Daily dose of X410
  - 14 oz.
- 14 hours operation
  - We will set the controller to pump for 1 minute every 10 minute period
    - (14 X 60)/10=
    - 84 ten minutes periods

$$\frac{Dose\ per\ day}{Daily\ periods}$$

$$\frac{14\ oz}{84\ periods} = 0.17\ o/p$$

$$\frac{100^{\%}}{1.28} \times \frac{x^{\%}}{0.17}$$

$$\frac{17}{1.28} = \frac{1.28X}{1.28}$$

$$X^{\%} = 13.3\%$$

Pump Sizing

- 13% ??
  - Is this a proper setting for a pump?

* A biocide pump should be capable of pumping the entire dosage within one hour or less

Use a:
- Smaller pump
- Less concentrated product

AWT

Non-Oxidizing Biocides (Volume Dose)

Label Usage Verification

- System data:
  - System volume
    - 2,424 gallons
- Product data:
  - Dosage rate: 250 ppm
  - Specific gravity: 1.012
  - Contact Time: 4 hours

$$\frac{V \times ppm}{120{,}000} = lbs.\,of\ product\ needed$$

$$\frac{2{,}424 \times 250}{120{,}000} = 5.05\ lbs.$$

$$\frac{Product\ lbs\ needed}{Product\ lbs.\,per\ gallon} = gallons\ of\ product$$

$$1.012 \times 8.345 = 8.45$$

$$\frac{5.05}{8.45} = 0.6\ gallons\ of\ product$$

$$0.6\ x\ 128 = \ 77\ oz\ of\ product\ needed$$

AWT

Pre-Bleed?

TraceCalc

$$\left(\frac{E \times CT}{V}\right)\mu \ = LC,$$

$$C - LC = Prebleed\ setting$$

- Definitions:
  - E = Evaporation (gpm)
  - CT= Contact time (minutes)
  - V= System volume (gallons)
  - μ= Makeup water conductivity
  - LC= Lock out concentration
  - C= Normal conductivity setpoint

AWT

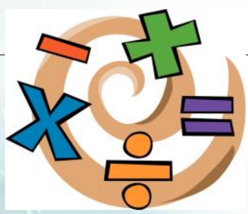
Oxidizing Biocides

- Slow and steady
  - Don't want spikes
- Options:
  - Volume feed on schedule
  - ORP Control

Oxidation **R**eduction **P**otential,
the tendency of a chemical species to acquire electrons and thereby be reduced

Price Determination

$$\begin{aligned}&(Product(s)dose \times doses\ per\ year \times cost\ per\ unit)\\ &\quad + Equipment\\ &\quad + Service\ fees\\ &\quad + etc\ \ldots\\ \hline &\quad \textbf{Price}\end{aligned}$$



OTHER EQUATIONS

Half Life

$$Half\ life = \frac{0.7\ x\ V}{B} \qquad Quarter\ life = \frac{1.4\ x\ V}{B}$$

- Definitions
  - V = volume
  - B = bleed rate (blowdown) gpm

*natural log(2) = 0.69
natural log(4) = 1.38

Theoretical Biocide Feed

$$ppm + (\frac{ppm \times CT}{HL})$$

- Definitions:
  - ppm = required ppm of product
  - CT = Contact time (minutes)
  - HL = Half life (minutes)

Theoretical Biocide Feed

$$ppm + (\frac{ppm \times CT}{HL})$$

- System data:
  - System volume
    - 2,424 gallons
  - Bleed
    - 1,260
      - (needs to be in gpm for half life)
  - Operates 14 hr/day
- Product data:
  - Dosage rate: 250 ppm
  - Specific gravity: 1.012
  - Contact Time: 4 hours (240 min)

$$Half\ life = \frac{0.7\ x\ V}{B}$$

$$B = \left(\frac{1260}{840}\right) = 1.5\ gpm$$

$$\frac{0.7\ x\ 2424}{1.5} = 1{,}131.2\ min.$$

$$250 + (\frac{250 \times 240}{1{,}131.2}) = 303\ ppm$$

Feeding Our Calculated Biocide

$$\frac{V \times ppm}{120{,}000} = lbs.\,of\ product\ needed$$

$$\frac{2{,}424 \times 303}{120{,}000} = 6.12\ lbs.$$

$$\frac{Product\ lbs\ needed}{Product\ lbs.\,per\ gallon} = gallons\ of\ product$$

- Product data:
  - Dosage rate
    - (with bleed for 4 hours)
      - 303 ppm
  - Specific gravity: 1.012
  - Volume 2,424

$$1.012 \times 8.345 = 8.45$$

$$\frac{6.12}{8.45} = 0.72\ gallons\ of\ product$$

$$0.72 \times 128 = 92\ oz$$

AWT

The Cost of Antiquated Equipment

This Is Being Green!

- 90oz – 77oz = 13 oz per dose
- 13oz x 7 doses a week = 91 oz extra per week
- 91 oz x 52 weeks per year = 4,732 oz extra per year
- 4,732 / 128 = 37 gallons extra per year
- Almost a 55 gallon drum's worth!

- How much does a 55 gallon drum of biocide cost?
  - Product
  - Shipping
  - Onsite storage regulations
  - Disposal…

AWT

Retention Time

$$\frac{V}{B} = D$$

- Definitions:
  - V= System volume
  - B= Bleed (gal/day)
  - D= Number of days
  - Volume= 2,809 Gallons
  - Bleed= 1,260 Gallons/Day

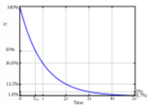
$$\frac{2{,}809}{1{,}260} = 2.23\ Days$$

AWT

Decay Formula

$$T = \frac{2.303 \times V\,(\log C_i - \log C_f)}{B}$$

- Definitions
  - T = Time
  - V = Volume
  - C_i = Initial concentration (ppm)
  - C_f = Final concentration (ppm)
  - B = Bleed rate



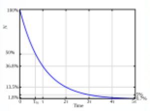
Decay Formula in Practice

$$T = \frac{2.303 \times V\,(\log C_i - \log C_f)}{B}$$

$$T = \frac{2.303 \times 3{,}500\,(\log 10{,}000 - \log 200)}{1}$$

- Definitions
  - T = Time
  - V = Volume
    - 3,500 Gallons
  - C_i = Initial concentration (ppm)
    - 10,000 ppm
  - C_f = Final concentration (ppm)
    - 200 PPM
  - B = Bleed rate
    - 1 gpm

T=13,695 Minutes
T=13,695/1440
T=9.5 Days



TraceCalc

Glycol Calculation

$$V\left(\frac{T - C}{100 - C}\right) = G$$

- Definitions:
  - V = Volume
  - T = Target concentration
  - C = Current concentration
  - G = the amount to be drained and filled with 100% glycol

TraceCalc

Glycol Calculation

$$V\left(\frac{T-C}{100-C}\right) = G$$

$$15{,}000\left(\frac{30-10}{100-10}\right) = G$$

G= 3,333

- Definitions:
  - V = Volume
    - 15,000 Gallons
  - T = Target concentration
    - 30%
  - C = Current concentration
    - 10%
  - G = the amount to be drained and filled with 100% glycol

AWT

Velocity

$$\frac{0.408 \times gpm}{P^2}$$

- Definitions:
  - GPM = gallons per minute
  - P^2 = Pipe interior diameter squared
  - Flow through 1" coupon assembly
    - 3 – 5 FPS
    - 8 – 13 GPM

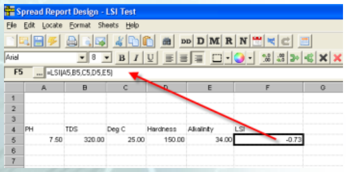
AWT

LSI, RSI, PSI

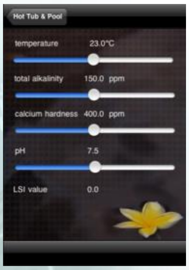
- It all starts with the Saturation pH (pH_s):
  12.3-(log CaH + log Malk + (0.025 x°C) - (0.011x$\sqrt{TDS}$))
  - **LSI**= pH – pH_s
    - *-3 to 3*
      - *<0 non-scaling tendency*
      - *>0 scaling tendency*
  - **RSI**= (2 x pH_s) – pH
    - 0 to 12
      - *<6 = scaling tendency*
      - *>6 = non-scaling tendency*
  - **PSI**= (2 x pH_s) - pH_{eq}
    - pH_{eq}= (1.465 x log Malk) + 4.54
      - *0 to 12*
        - *<6 = scaling tendency*
        - *>6 = non-scaling tendency*

AWT

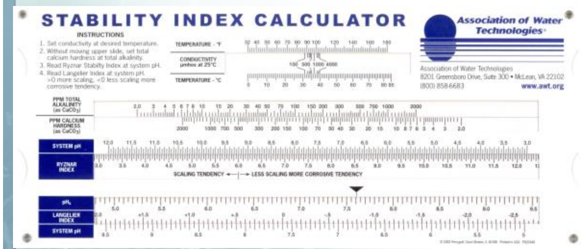
Computer Programs

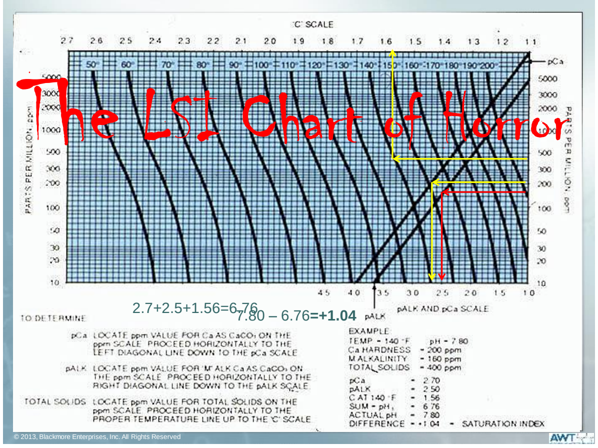


iPhone App

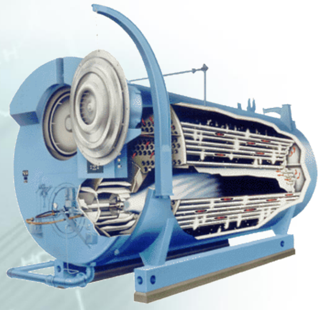


Slide Rules





Boiler Calculations



Ten Minute Break

Please be back in

00:00

Halftime Trivia

Who do we know these Rock artists as?

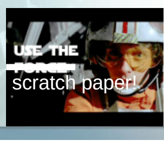
Paul David Hewson
David Robert Jones
Declan Patrick McManus
John Michael Osborne
Reginald Dwight

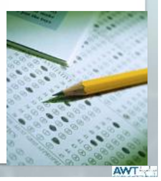
Who Are They?

Paul David Hewson	Bono
David Robert Jones	David Bowie
Declan Patrick McManus	Elvis Costello
John Michael Osborne	Ozzy Osborne
Reginald Dwight	Elton John

Taking The Test

- You have 3 things that are working against you when you start to take the test:
  - Unfamiliar with process
  - Worried about time limit
  - Ability to reason is very low



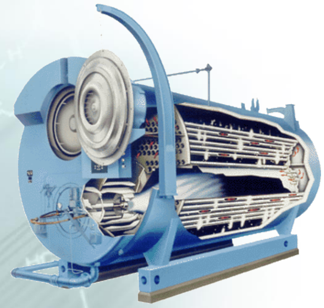


#12 Mary had a little lamb, its fleece was white as snow. What is the tensile strength of the lamb's fleece at room temperature?

A

B

Boiler Calculations



Boiler Calculations

- General survey:
  - Boiler system type
  - System design
  - Operating hours
  - Loading
  - System volume
- Technical data:
  - Product selection
    - Dosage rates
      - Concentration
    - Specific gravity
    - Pricing
    - Etc…

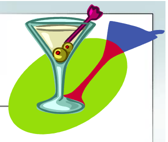
Maximum Concentration Ratio

$$\frac{Boiler\ water}{Feed\ water} = concentration\ ratio$$

- Limiting factors (ASME 0-300 PSI Firetube Boiler)
  - Silica 150 ppm
  - Alkalinity 700 ppm
  - Hardness 300 ppm
  - Conductivity
    - 3500 ppm neutralized (TDS)
    - 7000 µs/cm un-neutralized

  - The lowest number is the limiting factor

Shaken or Stirred



- Neutralized or un-neutralized conductivity?
  - ASME Limits
    - 7,000 µs/cm un-neutralized
    - 3,500 ppm neutralized
      - TDS x 1.35
      - 3500 x 1.35 = 4,725
        - Plus the OH^- conductivity factor = ±7,000 µs/cm

Maximum Concentration Ratio

Impurities	Feed Water Residuals	ASME Limits
Total Hardness	0.5 ppm	300 ppm
Total Alkalinity	23 ppm	700 ppm
Silica	3 ppm	150 ppm
Conductivity	140 µs/cm	7000 µs/cm

ASME Recommended Boiler Control Limits

ASME Recommended Boiler Control Limits

	Watertube		*Firetube*
Pressure	*0-300*	*301-600*	*0-300*
	Feedwater		
Oxygen	<0.007	<0.007	<0.007
Iron	<0.10	<0.05	<0.10
Copper	<0.05	<0.025	<0.05
Hardness	<0.5	<0.3	<1.0
pH	8.3-10.5	8.3-10.5	8.3-10.5
TOC	<1	<1	<10
Oil	<1	<1	<1
	Boiler Water		
Silica	<150	<90	<150
M Alk	<1000	<850	<700
Un-Neut. Cond	<7000	<5500	<7000

ASME
SETTING THE STANDARD

The “Magic” Equation

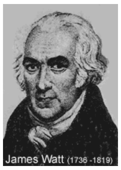
$$FW = CR + MU = E + B$$

- Using the information you have, you can factor out what information you need.
  - Feedwater = E + B or CR + MU
  - Condensate return = MU – FW
  - Makeup = (E + B) – CR
  - Evaporation = FW – B
  - Bleed = FW – E

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

1 boiler HP = 34.5 lbs. of steam/hr

What is a Horsepower?



1 HP=
- 746 watts
- 2,545 BTU’s

The “Magic” Equation

$$FW = CR + MU = E + B$$

- What we know:
  - 150 HP Boiler

$E=?$

$E = 150 \times 34.5 = 5{,}175\ lbs/hr$

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

Blowdown

$$B = \frac{E}{CR-1} \qquad B = \frac{150\ hp\ x\ 34.5}{30-1}$$

B=178.4 lbs/hr

- What we know:
  - 150 HP Boiler
  - Concentration ratio: 30
  - E=5,175
- Definitions:
  - E = Evaporation, steam generation lbs./hr.
  - CR = Concentration Ratio

Condensate Return

$$100-\left(\frac{FW_{tds}\times 100}{Mu_{tds}}\right)\text{=CR}$$

$$100-\left(\frac{140\times 100}{200}\right)\text{=30\%}$$

$$0.30\ x\ 5{,}175\ =\ 1{,}553\ \text{lbs/hr}$$

- What we know:
- FW tds= 140
- MU tds= 200
- Definitions:
  - FW_{tds} = Total dissolve solids in feedwater
  - Mu_{tds} = Total dissolved solids in makeup water
  - CR = % condensate returned

The "Magic" Equation

$$FW = CR + MU = E + B$$

E= 150×34.5 =5,175

- What we know:
  - 150 HP Boiler
  - 30% Condensate Return
  - Concentration ratio: 30

Definitions:
- FW = Feedwater
- CR = Condensate return
- MU = Makeup
- E = Evaporation
- B = Bleed

The “Magic” Equation

$$FW = CR + MU = 5{,}175 + B$$

CR= 5,175 × .30 =1,552.5 (let's round up)

- What we know:
  - 150 HP Boiler
  - 30% Condensate Return
  - Concentration ratio: 30

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

AWT

The “Magic” Equation

$$FW = 1{,}553 + MU = 5{,}175 + B$$

- What we know:
  - 150 HP Boiler
  - 30% Condensate Return
  - Concentration ratio: 30

B=$\frac{5{,}175}{30-1} = 178.4$ (let's round down)

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

AWT

$$FW = CR + MU = E + B$$

The “Magic” Equation

$$FW = 1{,}553 + MU = 5{,}175 + 178$$

- What we don’t know:
  - Mu
  - FW

CR + MU = E + B
Mu = (E + B) - CR
Mu = 5,353 - 1,553
Mu = 3,800

FW = CR + MU
FW = 1,553 + 3,800
FW = 5,353

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

AWT

The “Magic” Equation

$$FW = CR + MU = E + B$$

Mass Balance

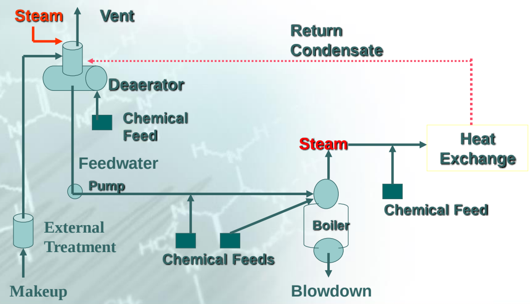
$$5{,}353 = 1{,}553 + 3{,}800 = 5{,}175 + 178$$

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

$$FW = CR + MU = E + B$$

$$5{,}353 = 1{,}553 + 3{,}800 = 5{,}175 + 178$$

Mass Balance



$$FW = CR + MU = E + B$$

Converting from Lbs/Hr to Gal/Hr

$$5{,}353 = 1{,}553 + 3{,}800 = 5{,}175 + 178$$

- Water weighs 8.345 lbs./gal

- FW= 5,353 / 8.345 = 641 g/h
- CR= 1,553 / 8.345 = 186 g/h
- MU= 3,800 / 8.345 = 455 g/h
- E= 5,175 / 8.345 = 620 g/h
- B= 178 / 8.345 = 21 g/h

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

$$FW = CR + MU = E + B$$

Transforming The Equation From Gal/Hr to Gal/Day

$$641 = 186 + 455 = 620 + 21$$

- Hours in a day= 24

- FW= 641 g/h x 24 h/d = 14,904 gpd
- CR= 186 g/h x 24 h/d = 4,464 gpd
- MU= 455 g/h x 24 h/d = 10,920 gpd
- E= 620 g/h x 24 h/d = 14,880 gpd
- B= 21 g/h x 24 h/d = 504 gpd

Definitions:
FW = Feedwater
CR = Condensate return
MU = Makeup
E = Evaporation
B = Bleed

lbs.	Capacity in grains
6	20,000
*10	25,000
15	30,000

Softener Equations

$$\frac{Total\ Hardness\ ppm}{17.1} = grains\ per\ gallon$$

$$\frac{Grains\ per\ gallon \times gallons\ req.\ before\ regeneration}{Grains\ capacity} = cubic\ feet\ of\ resin\ needed$$

- 1 grain of hardness/gallon = 17.1 ppm of total hardness (as $CaCO_3$)

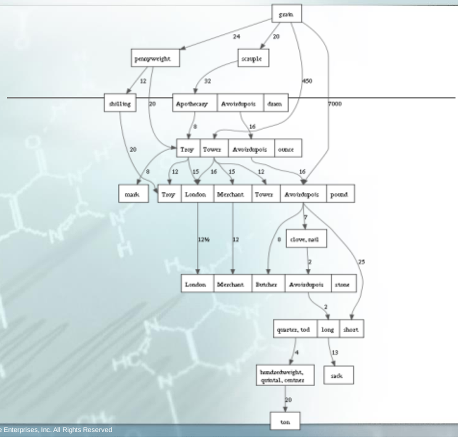
- @ 10 lbs. of salt per cubic foot, you will yield 25,000 grains of capacity, or 427,500 ppm of total hardness capacity (per ft^3)

- Resin Repalcement:
  - Resin Capacity= $\Pi r^{2\prime} H'$ x 66%

How do we get 17.1??

$$\frac{1}{7000} \times 120{,}000 = 17.1$$

- A grain is a unit of measurement, mass, based upon the weight of a single seed or "grain."
  - 7,000 grains = 1 pound
    - (1 grain = 0.065 grams)



Softener Equations

- MU total hardness= 25 ppm
- We want the resin to last 2 days before regenerating
- MU= 10,920 gpd $\frac{Total\ Hardness\ ppm}{17.1} = grains\ per\ gallon$
- 10lbs. of salt yields 25,000 grains of capacity

$$\frac{25\ PPM}{17.1} = 1.46 \text{ Grains}$$

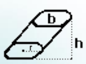
$$\frac{Grains\ per\ gallon \times gallons\ req.per\ regeneration}{Grains\ capacity} = cubic\ feet\ of\ resin\ needed$$

$$\frac{1.46\ x\ 21{,}840}{25{,}000} = 1.28\ Ft^3 \text{ of resin}$$

Softener Equations

- Softener Dimensions:
  - Diameter: 12″
  - Height: 65″

Resin Capacity= $\Pi r^2 H' \times 66\%$



$\frac{12"}{12"} = 1'$ $\frac{1'}{2} = 0.5'$

$\frac{65"}{12"} = 5.42'$

$$3.14 \times (0.5\ x\ 0.5) \times 5.42$$

$$3.14 \times 0.25 \times 5.42 = 4.25$$

$$4.25 \times 0.66 = \ 2.8\ Ft^3 \text{ of resin}$$

Boiler Product Equations

Based on our mass balance equation

$$FW = CR + MU = E + B$$

$$5{,}353 = 1{,}553 + 3{,}800 = 5{,}175 + 178$$

All in lbs. per hour

AWT

Sulfite

SO_3

$$(O_2 \times 7.88) + \left(\frac{SO_{3_{Req}} \ x\ 1.6}{CR}\right) = Na_2SO_{3_{\#}}$$

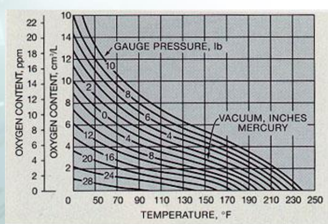
- Definitions:
  - O_2 = O_2 content from chart
  - $SO_{3_{Req}}$ = SO_3 required
  - CR = Concentration Ratio
  - FW = Feedwater
  - $Na_2SO_{3_{\#}}$ = lbs. of dry Na_2SO_3 per 1,000,000 lbs of FW

ESTIMATED O_2 CONTENT OF FEEDWATER (FOR CALCULATING SO_3 DEMAND)	
FEEDWATER TEMP	PPM O_2
50	11.10
60	10.00
70	9.01
80	8.22
90	7.50
[illegible]	6.86
110	6.29
120	7.72
130	5.15
140	4.72
150	4.29
160	3.86
170	3.43
180	2.72
190	2.00
200	1.29
210	0.58
DEAERATER	USE 0.007

Feedwater Management

AWT

O2 Content Graph



AWT

Sulfite

SO_3

$$O_2 \times 7.88 + \left(\frac{SO_{3_{Req}} \; x \; 1.6}{CR}\right) = Na_2SO_{3_\#}$$

$$2 \times 7.88 + \left(\frac{45 \; x \; 1.6}{30}\right) =$$

$$15.76 + (2.4) = 18.16_\#$$

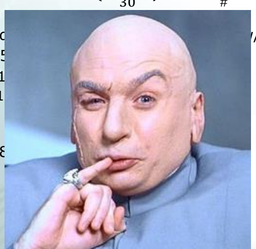
- What we know:
  - FW Temp= 190°F
  - 45 PPM residual required
  - CR= 30
- Definitions:
  - O_2 = O_2 content from chart
  - $SO_{3_{Req}}$ = SO_3 required
  - CR = Concentration Ratio
  - FW = Feedwater
  - $Na_2SO_{3_\#}$ = lbs. of dry Na_2SO_3 per 1,000,000 lbs. of FW

ESTIMATED O_2 CONTENT OF FEEDWATER (FOR CALCULATING SO_3 DEMAND)	
FEEDWATER TEMP ^{0}F	PPM O_2
50	11.10
60	10.00
70	9.01
80	8.22
90	7.50
100	6.86
110	6.29
120	7.72
130	5.15
140	4.72
150	4.29
160	3.86
170	3.43
180	2.72
190	2.00
200	1.29
210	0.58
DEAERATER	USE 0.007

How Much Do We Need?

$$2 \times 7.88 + \left(\frac{45 \; x \; 1.6}{30}\right) = 18.16_\#$$

- $18.16_\#$ = lbs. need … /day
- Our Boiler FW = 5
  - 5,353 x 24 = 1
    - 128,472 / 1
- So, 18.16 x 0.128



Phosphate

$$Ca + \left(\frac{PO_4 \times 1.5}{CR}\right) = DSP$$

- Definitions:
  - Ca = Calcium hardness in feedwater
  - PO_4 = Desired phosphate residual in boiler
  - CR= Concentration Ratio
  - DSP = Disodium phosphate per 1 mil lbs. of FW
    - Conversions:
      - Sodium Tripolyphosphate:
        - DSP x 0.83
      - Sodium Hexametaphosphate:
        - DSP x 0.72

Phosphate

$Ca + (\frac{PO_4 \times 1.5}{CR})$=DSP $0.5 + (\frac{30 \times 1.5}{30})$=

$0.5 + (1.5)$=$2_{\#}$

- What we know:
  - Cal Hardness: 0.5 ppm in FW
  - We want 30 ppm PO_4 residual
  - Concentration ratio= 30
- Definitions:
  - Ca = Calcium hardness in feedwater
  - PO_4 = Desired phosphate residual in boiler
  - DSP = Disodium phosphate per 1 mil lbs. of FW
    - Conversions:
      - Sodium Tripolyphosphate:
        - x 0.83
      - Sodium Hexametaphosphate:
        - x 0.72

How Much Do We Need?

$$0.5 + (\frac{30 \times 1.5}{30})=2_{\#}$$

- $2_{\#}$ = Lbs. needed per 1,000,000 lbs. of FW flow/day
- Our Boiler FW = 5,353 lbs/hr
  - 5,353 x 24 = 128,472 lbs/day
    - 128,472 / 1,000,000= 0.128
- So, 2 x 0.128 = 0.256 lbs of DSP per Day
  - The product is only 30% active:
    - 0.256 x (100/30)= 0.85 lbs per day of product
- What if your product was in the hexameta form?
  - 0.85 lbs. x's 0.72 = 0.612 lbs

Alkalinity

Ion	P=0	P<M/2	P=M/2	P>M/2	P=M
OH	0	0	0	2P-M	M
CO_3	0	2P	M	2(M-P)	0
HCO_3	M	M-2P	0	0	0

Alkalinity

$$(0.67 \times FW_{CaH})+(FW_{MgH}-FW_{MAlk}+\frac{P_{Alk}}{CR})=\#$$

- FW_{CaH} = Feedwater calcium hardness*
- FW_{MgH} = Feedwater magnesium hardness*
- FW_{Malk}= Feedwater M alkalinity
- P_{alk}= Required boiler water P Alkalinity*
- CR= Concentration Ratio
- #= lbs. of NaOH per 1,000,000 lbs. of FW flow
    - *as ppm $CaCO_3$
    - 0.67 is the molar ratio for $2(PO_4)^-$ and $3Ca^+$

Alkalinity

$$(0.67 \times FW_{CaH})+(FW_{MgH}-FW_{MAlk}+\frac{P_{Alk}}{CR})=\#NaOH$$

- FW_{CaH} = 0.7 ppm
- FW_{MgH} = 0.2 ppm
- FW_{Malk}= 12 ppm
- P_{alk}= 300 ppm
- CR= 15 ↖ ?

$$(0.67 \times 0.7)+(0.2-12+\frac{300}{15})$$

$$(0.469)+(0.2-12+20)$$

$$(0.469)+(0.2 + (-12) +20)$$

$$(0.469)+(-11.8+20)=8.7 \text{ lbs.}$$

NaOH to KOH = x 1.4

How Much Do We Need?

$$(0.67 \times 0.7)+(0.2-12+\frac{300}{15})=8.7 \text{ lbs.}$$

- 8.7 lbs. is the amount of 100% active product required for 1,000,000 lbs. of FW flow/day
- Our Boiler FW = 5,353 lbs/hr
    - 5,353 x 24 = 128,472 lbs/day
        - 128,472 / 1,000,000= 0.128
- So, 8.7 x 0.128 = 1.11 lbs. of 100% active product/day
- What if we have a 50 % active product:
    - 1.11 x (100/50) = 2.22 lbs of product/day

Polymer

$$\frac{ppm}{CR} = \#'s$$

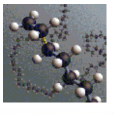
- Definitions:
  - ppm = The required product concentration (ppm)
  - CR = Concentration Ratio
  - #'s = lbs. of product per 1,000,000 lbs. of FW flow
    - Typical boiler water programs are designed for 30-45 ppm of active polymer

Polymer

$$\frac{ppm}{CR} = \#'s$$

- Definitions:
  - ppm = 360 ppm
  - CR = 30

$$\frac{360}{30} = 12\ \#'s/\text{day}$$



How Much Do We Need?

$$\frac{360}{30} = 12\ \#'s/\text{day}$$

- 12 lbs. is the amount of product required for 1,000,000 lbs. of FW flow/day
- Our Boiler FW = 5,353 lbs/hr
  - 5,353 x 24 = 128,472 lbs/day
    - 128,472 / 1,000,000= 0.128
- So, 12 x 0.128 = 1.5 lbs. of product/day

Chelant

$$(FW_{TH}+FW_{Fe}+FW_{Cu})+(\frac{BW_c}{CR}\times\frac{100}{\%_{EDTA}})$$

- FW_{TH} = Feedwater total hardness × 10
- FW_{Fe} = Feedwater iron × 17.9
- FW_{Cu} = Feedwater copper × 15.7
- BW_C = Required boiler water chelant residual (1-3 ppm)
- CR = Concentration ratio
- $\%_{EDTA}$ = % EDTA in product
  - *Hardness, Iron, Copper are calculated using 38% EDTA

Chelant

$$(FW_{TH}+FW_{Fe}+FW_{Cu})+(\frac{BW_c}{CR}\times\frac{100}{\%_{EDTA}})$$

- FW_{TH} = 0.2 ppm total hardness × 10
- FW_{Fe} = 0.5 ppm iron × 17.9
- FW_{Cu} = 0.01 ppm copper × 15.7
- BW_C = 2 ppm
- CR = 30
- $\%_{EDTA}$ = 20 % EDTA in product

$$((0.2 \text{ x } 10)+(0.5 \text{ x } 17.9)+(0.01 \text{ x } 15.7))+(\frac{2}{30}\times\frac{100}{20})=$$

$$(2+8.95+0.157)+(0.066\times5)=$$

$$(11.1)+(0.33)=11.4_{\#}$$

How Much Do We Need?

$$11.1+(\frac{2}{30}\times\frac{100}{20})=11.4_{\#}$$

- $11.4_{\#}$ = The amount of product we need per 1,000,000 lbs. of FW flow/day
- Our Boiler FW = 5,353 lbs/hr
  - 5,353 x 24 = 128,472 lbs/day
    - 128,472 / 1,000,000= 0.128
- So, 11.4 x 0.128 = 1.46 lbs of product per Day

Boiler Product Equations

Based on our mass balance equation

$$FW = CR + MU = E + B$$

$$5{,}353 = 1{,}553 + 3{,}800 = 5{,}175 + 178$$

All in lbs. per hour

AWT

Ion	P=0	P<M/2	P=M/2	P>M/2	P=M
OH	0	0	0	2P-M	M
CO_3	0	2P	M	2(M-P)	0
HCO_3	M	M-2P	0	0	0

Steamline Treatment

FW pH < 8.3

Bicarbonate alkalinity equation:

$$\frac{0.79}{M_{alk}} \times F'$$

FW pH > 8.3

Carbonate alkalinity equation:

$$\frac{0.35}{P_{alk}} \times F'$$

- Definitions:
  - M_{alk} = Bicarbonate (total) alkalinity in condensate return
  - P_{alk} = Carbonate alkalinity in condensate return
  - F' =
    - 4 – 6 ppm of 50% neutralizing amine (any blend)
      - Allows for recycling of amines
    - 1 – 3 ppm of 100% active filming amines
      - Emulsions are normally 5-10% active

AWT

Steamline Treatment

Bicarbonate alkalinity equation:

$$\frac{0.79}{M_{alk}} \times F'$$

Carbonate alkalinity equation:

$$\frac{0.35}{P_{alk}} \times F'$$

$$\frac{0.35}{23} \times 5 = 0.08_{\#}$$

- Definitions:
  - pH of condensate = 8.5, so we will use the carbonate equation
  - P_{alk} = 23 ppm
  - F' =5 ppm

AWT

How Much Do We Need?

$$\frac{0.35}{23} \times 5 = 0.08_{\#}$$

- $0.08_{\#}$ = The amount of product we need per 1,000,000 lbs. of <u>STEAM</u> flow/day
- Our Boiler:
  - E = 5,175 lbs/hr
  - 5,175 x 24 = 124,200 lbs/day
  - 124,200 / 1,000,000 = 0.124
- So, 0.08 x 0.124 = 0.009 lbs/ of product per Day
- Let's change to a 5% active product
- 0.009 x (100/5) = 0.18

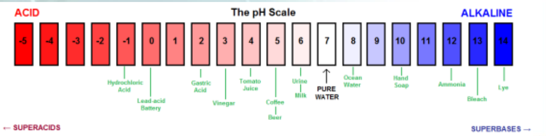
Thermodynamic Properties of Saturated Steam
(condensed table)

Gauge Pressure (psig)	Absolute Pressure (psia)	Steam Temp (°F)	Enthalpy of Sat. liquid (Btu/lb)	Latent Heat (Btu/lb)	Enthalpy of Steam (Btu/lb)	Specific Volume (ft^3/lb) $(density)^{-1}$
---	---	---	In a Vacuum	---	---	---
29.74	0.0885	32	0	1075.8	1075.8	3306
29.52	0.2	53.14	21.21	1063.8	1085	1526
27.89	1	101.74	69.7	1036.3	1106	333.6
19.74	5	162.24	130.13	1001	1131.1	73.52
9.56	10	193.21	161.17	982.1	1143.3	38.42
7.54	11	197.75	165.73	979.3	1145	35.14
5.49	12	201.96	169.96	976.6	1146.6	32.4
3.45	13	205.88	173.91	974.2	1148.1	30.06
1.42	14	209.56	177.61	971.9	1149.5	28.04
--Psig--	---	---	---	---	---	---
0.0	14.696	212.00	180.07	970.3	1150.4	26.80
1.3	16.0	216.32	184.42	967.6	1152.0	24.75
2.3	17.0	219.44	187.56	965.5	1153.1	23.39
5.3	20.0	227.96	196.16	960.1	1156.3	20.09
10.3	25.0	240.07	208.42	952.1	1160.6	16.30
15.3	30.0	250.33	218.82	945.3	1164.1	13.75
20.3	35.0	259.28	227.91	939.2	1167.1	11.90
25.3	40.0	267.25	236.03	933.7	1169.7	10.50
30.3	45.0	274.44	243.36	928.6	1172.0	9.40
40.3	55.0	287.07	256.30	919.6	1175.9	7.79
50.3	65.0	297.97	267.50	911.6	1179.1	6.66
60.3	75.0	307.60	277.43	904.5	1181.9	5.82
70.3	85.0	316.25	286.39	897.8	1184.2	5.17
80.3	95.0	324.12	294.56	891.7	1186.2	4.65
90.3	105.0	331.36	302.10	886.0	1188.1	4.23
100.0	114.7	337.90	308.80	880.0	1188.8	3.88
110.3	125.0	344.33	315.68	875.4	1191.1	3.59
120.3	135.0	350.21	321.85	870.6	1192.4	3.33
125.3	140.0	353.02	324.82	868.2	1193.0	3.22
130.3	145.0	355.76	327.70	865.8	1193.5	3.11
140.3	155	360.50	333.24	861.3	1194.6	2.92
150.3	165	365.99	338.53	857.1	1195.6	2.75
160.3	175.0	370.75	343.57	852.8	1196.5	2.60
180.3	195.0	379.67	353.10	844.9	1198.0	2.34
200.3	215.0	387.89	361.91	837.4	1199.3	2.13
225.3	240.0	397.37	372.12	828.5	1200.6	1.92
250.3	265.0	406.11	381.60	820.1	1201.7	1.74
-	300.0	417.33	393.84	809.0	1202.8	1.54
-	400.0	444.59	424.00	780.5	1204.5	1.16
-	450.0	456.28	437.20	767.4	1204.6	1.03

Testing Math

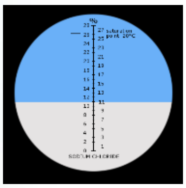
pH

- pH = $-\log_{10}(H^+)$



Salinity

- Salinity = 1.806 x Cl^-



Temperature Conversion

- **°F to °C**

  $(°F - 32)\frac{5}{9}$

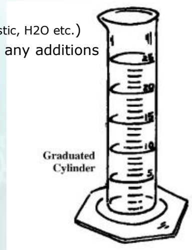
- **°C to °F**

  $(°C + 32)\frac{9}{5}$

Correcting for Volume Additions

$$\frac{TV}{SV} = VCF$$

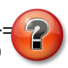
- Definitions:
  - TV= Total volume (sample + acid, caustic, H2O etc.)
  - SV= Original sample volume before any additions
  - VCF= Volume correction factor



Test Manipulation, Titration

$$\frac{ppm_s}{\left(\frac{V_n}{V_o}\right)} = \text{ppm}_n$$

$$\frac{50}{\left(\frac{50}{5}\right)} =$$

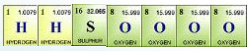


- Definitions:
  - V_n = New sample volume
  - V_o = Original sample volume
  - ppm_s = standard ppm count per drop
  - ppm_n = new ppm count per drop

Molarity

- Mole:
  - 1 molecular weight of any substance expressed in grams.
    - 1 mole of sodium is 23 grams
- Molar Solution (1M):
  - 1 molecular weight of any substance in 1 liter of water
- Equivalent:
  - The molecular weight of any substance expressed in grams which will supply or react with one Mole of (H^+) in an acid-base reaction
- Normality (N):
  - A 1 N solution contains 1 equivalent weight of any substance expressed in grams, in 1 liter of water

0.02N Sulfuric Acid



- This means that one liter of sulfuric acid solution contains 0.02 equivalents of sulfuric acid.
  - Molecular weight = 98g
- The equivalent mass is one half the molar mass, since each molecule of H_2SO_4 supplies two hydrogen atoms to neutralize alkaline materials.
  - 1 equivalent of H_2SO_4 = 98g/2 = 49.05g

$$W = (V)(N)(E)$$

$$W = (1\ liter)(0.02N)(49.05g\ \ )$$

Definitions:
W= Weight (grams)
V= Volume
N= Normality
E= Equivalent weight

So, 0.98 grams of H_2SO_4 diluted to 1 liter
Will give you 0.02N H_2SO_4

Questions