Water Balance

Mineral Saturation Control

- Water is the universal solvent
- Law of chemical equilibrium
  - Water will dissolve things until it becomes saturated
  - When water becomes oversaturated, excess material will be lost by precipitation
- Balanced, aggressive, scaling
- Analogy: cream & sugar in a cup of coffee
- Measured using the Langelier Saturation Index

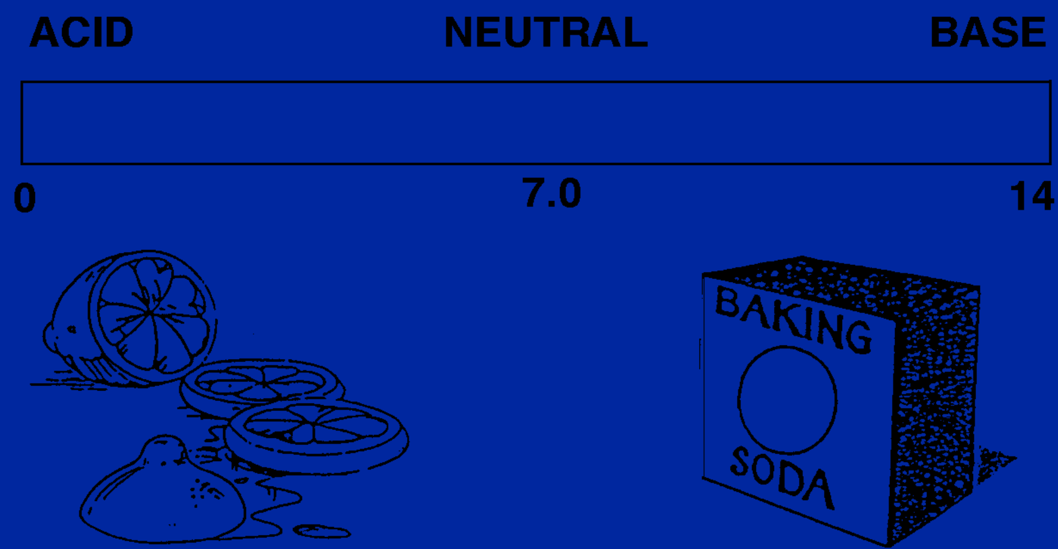
Water Balance

- pH
- Total alkalinity
- Calcium hardness
- Water temperature
- Total dissolved solids

pH

- pH is the negative base 10 logarithm of the hydrogen ion concentration of water
  (ex. 0.0000001 = 1.0 x 10^{-7} = pH of 7.0)
- pH is a measure of the acidity or alkalinity of the water
- Determined by the concentration of hydrogen ions in a specific volume of water
- Keeping pool water within ideal pH ranges increases bather comfort, and prevents damage to the pool and its related equipment
- pH range is specified by code (7.2 - 8.0 typical range)

pH



- pH is measured on a logarithmic scale from 0 (acids) to 14 (base), 7.0 (neutral)

pH

- Low pH levels:
  - Chlorine dissipates rapidly
  - Equipment corrodes
  - Pool surface materials etch or crack
- High pH levels:
  - Less hypochlorous acid (HOCl) forms
  - ORP levels plummet
  - Water clouds
  - Scaling occurs
  - Filter runs shorten
  - Circulation pipes calcify
  - Algae growth may increase

Causes of pH Change

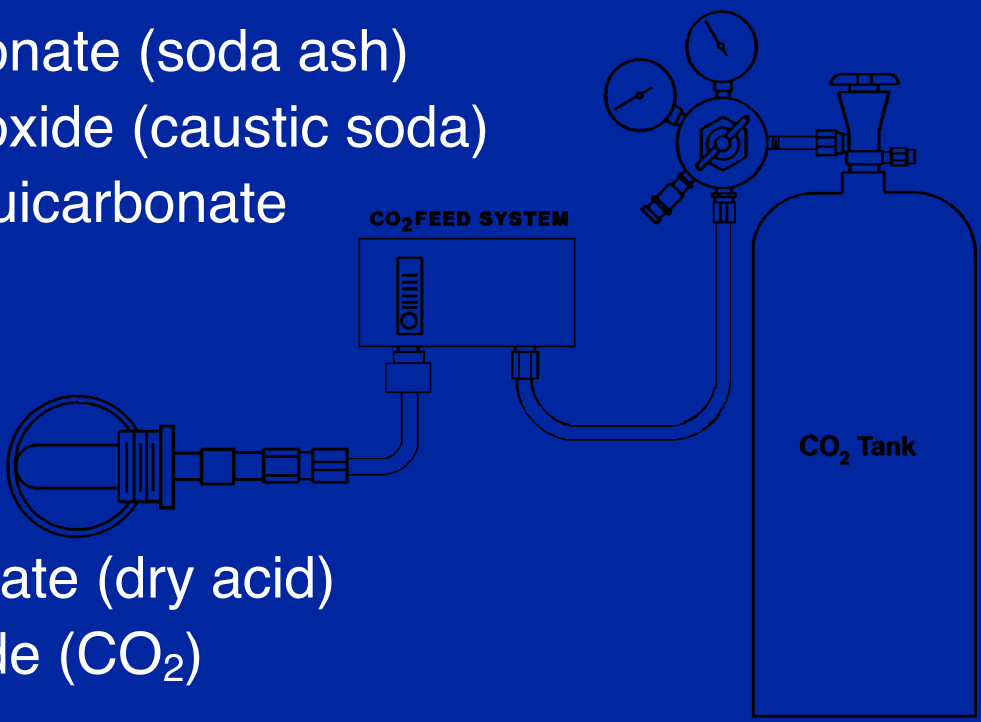
- Chemicals
- Rain
- Pollution
- Make-up water
- Plaster and other pool surface materials and equipment
- Swimmer waste products

pH Values of Common Pool Chemicals

- Muriatic acid 0.1
- Gas chlorine < 1.0
- Sodium bisulfate 1.4
- Trichlor 2.9
- Cyanuric acid 3.0
- Bromine 4.0
- Dichlor 6.9
- Carbon dioxide 6.9
- Sodium carbonate 8.3
- Sodium sesquicarbonate 10.1
- Lithium hypo 10.7
- Calcium hypo 11.8
- Sodium carbonate 13.0
- Sodium hypo 13.0

pH Adjustment Chemicals

- Raise
  - Sodium carbonate (soda ash)
  - Sodium hydroxide (caustic soda)
  - Sodium sesquicarbonate



- Lower
  - Muriatic acid
  - Sodium bisulfate (dry acid)
  - Carbon dioxide (CO_2)
  - Boric acid

Total Alkalinity

- Measure of the resistance ability of water to changes in pH
- Sum of all the alkaline minerals in the water
  - Primarily in bicarbonate form in swimming pools
  - Also as sodium, calcium, magnesium and potassium carbonates and hydroxides
- Acceptable range: 80 - 150 ppm
- Ideal range: 100 - 120 ppm
- Low total alkalinity:
  - "pH bounce"
  - Corrosion of pipes and staining of pool walls

Total Alkalinity

- High total alkalinity:
  - Over stabilization of the water
  - Extremely high acid demands
  - Formation of bicarbonate scale
  - May result in the formation of a white carbonate precipitate which will cloud the water
- To raise - add sodium bicarbonate (baking soda)
- To lower - add sodium bisulfate (dry acid)

Relationship Between pH & Total Alkalinity

- pH is the logarithm of the reciprocal of the hydrogen ion concentration of a solution and indicates to what degree a solution is acidic or basic
- The pH of a solution does not indicate the total amount of acid or base in the water, but only how much of it is ionized
- Total alkalinity is a measure of the pH buffering capacity or the water's resistance to changes in pH
- Total alkalinity consists of all the alkaline chemicals in the water, especially carbonates, bicarbonates and hydroxides

Relationship Between pH & Total Alkalinity

- At a pH of 7.2-7.6, most of the carbonate ions are in the bicarbonate form to provide buffering
- At high pH conditions, too much carbonate forms, calcium ions precipitate causing cloudy water or scale
- At low pH conditions, all of the carbonate ions are converted to bicarbonates. No calcium carbonate is formed and water becomes aggressive.

Total Alkalinity Adjustment

Formulas Developed by Kim Skinner and J. Que Hales of Pool Chlor

Lowering Total Alkalinity with Muriatic Acid

(Volume ÷ 125,000) x ____ ppm desired change = ____ quarts

Lowering Total Alkalinity with Sodium Bisulfate

(Volume ÷ 47,056) x ____ ppm desired change = ____ pounds

Total Alkalinity Adjustment

Formulas Developed by Kim Skinner and J. Que Hales of Pool Chlor

Raising Total Alkalinity with Sodium Bicarbonate

(Volume ÷ 71,425) x ___ ppm desired change = ___ pounds

Raising Total Alkalinity with Sodium Carbonate*

(Volume ÷ 113,231) x ___ ppm desired change = ___ pounds

Raising Total Alkalinity with Sodium Sesquicarbonate

(Volume ÷ 80,000) x ___ ppm desired change = ___ pounds

* Use sodium carbonate only if both pH and total alkalinity need to be raised, and TDS and calcium hardness levels are low --otherwise a white calcium carbonate precipitate will be formed

Calcium Hardness

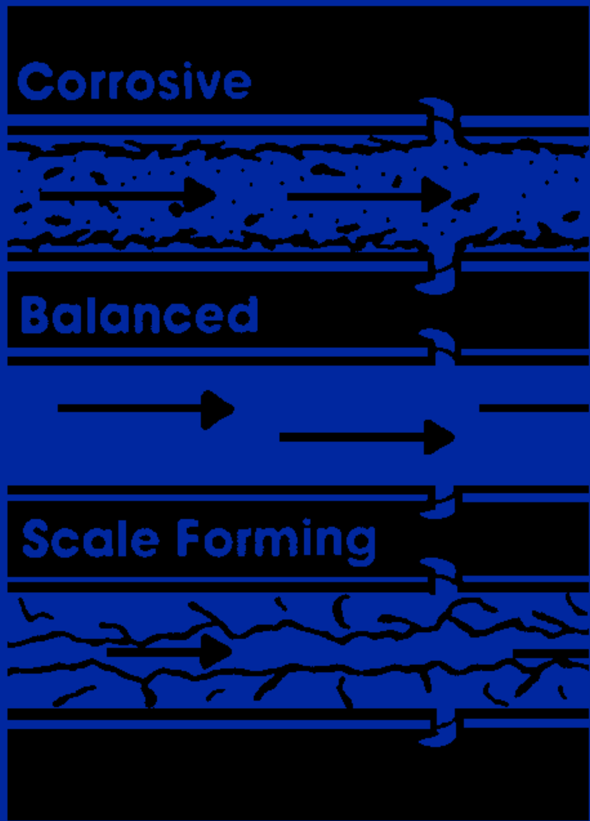
- Calcium hardness is a measure of the temporary carbonate hardness or calcium ion content of water
- Water hardness levels should be maintained between 200 and 400 ppm in most pools
- Water that is too hard:
  - Causes scale formation
  - Raises the pH
  - Clouds the water
  - Decreases the flow rate

Calcium Hardness

- Maintaining low calcium levels (soft water):
  - Plaster may soften or etch
  - Corrosion and staining will intensify
  - Vinyl liners will crack
  - Tile grout will be dissolved into the water and tiles will pop off the pool walls
- To raise calcium hardness: add calcium chloride dihydrate
- To lower calcium hardness: nanofiltration, dilute, sodium hexametaphosphate, cellulose fiber

Unbalanced Water

- Damage to pipes caused by unbalanced water conditions



Sodium Hexametaphosphate

- 5 ppm will prevent the undesirable effects of excessive water hardness
- Initial dose
  - Add 10 pounds per 250,000 gallons of pool water
- Maintenance dose every 2 weeks
  - Add 2 pounds per 250,000 gallons of pool water
- Warning: strongly acidic
- Recommended by the Texas Dept. of Health in their text "Training Course for Swimming Pool Operators"

Water Temperature

- Appropriate water temperatures vary by:
  - Region of the country
  - Priority facility usage
  - Primary programming
  - Age of participants
  - Typical temperatures:
    - 104° F Spas - maximum temperature
    - 86° - 94° Therapy pools
    - 83° - 86° Multi-use pools
    - 78° - 82° Competitive pools
- Calcium is less soluble in warm water
- Chemical usage goes up as temperature increases

Water Temperature

- Cooler temperatures are needed for:
  - High level competitive swimming and aerobic fitness activities
  - Activities in which swimmers are generating a lot of heat that needs to be dissipated
- Warmer temperatures are needed for:
  - Instructional programs
  - Low level fitness and health maintenance programs
  - Therapeutic programs
  - Programs catering to young children or seniors

Water Temperature

- If the water feels too warm:
  - Don’t wear a bathing cap
  - Drink plenty of water
  - Reduce the level of intensity at which you’re working out
- If the water feels too cold:
  - Wear a bathing cap
  - Wear a Lycra dive skin or neoprene wet suit
  - Work faster and harder so that you use more energy and generate more heat
  - Make sure air temperature is being maintained 2 - 7 degrees warmer than pool water temperature

Total Dissolved Solids

- All products dissolved in the water, including chemicals, bather waste products, pollution and windborne debris, contribute to the build-up of TDS
- As TDS increase:
  - Sanitizer effectiveness (ORP) is reduced
  - Algae growth increases
  - Water becomes cloudy
  - Scaling increases
  - Natural corrosion increases and staining increases
- Drain and refill the pool when TDS exceeds 1,500 ppm

Total Dissolved Solids

- Potable water 200 - 600 ppm
- Brackish water 3,000 - 5,000 ppm
- Sea water 35,000 ppm
- Great Salt Lake 260,000 ppm

Total Dissolved Solids

- Volume (in gallons) x 8.33 (weight of 1 gallon of water) = Weight of the water in the pool (in pounds)
- 1,000,000 ÷ weight of water in the pool = ppm TDS will increase for every 1 pound of solids added
- Equivalents:
  - 1 pound of any dry chemical = 1 pound of dissolved solid
  - 1 gallon of muriatic acid = 1.87 pounds of dissolved solid
  - 1 gallon of sodium hypochlorite = 2.2 pounds dissolved solid

TDS Increases

Example 1: 360,000 gallon pool

360,000 gallons x 8.33 lbs = 2,998,800 lbs

1,000,000 ÷ 2,998,800 lbs = 0.33 ppm/lb

Adding 100 lbs of sodium carbonate would increase TDS
0.33 x 100 lbs = 33 ppm

Example 2: 1,200 gallon spa

1,200 gallons x 8.33 lbs = 9,996 lbs

1,000,000 ÷ 9,996 lbs. = 100 ppm/lb

Adding 1 cup of sodium hypochlorite would increase the TDS 100 ppm/lb x .5 lbs (1 cup = 8 oz = .5 lbs) x 2.2 (1 g sodium hypo = 2.2 lbs of dissolved solid) = 110 ppm

Frequency of Draining Pools to Control for TDS Build-up

Volume

÷ 3

÷ Average # of bathers per day

= # of days between drainings

Examples:

(300,000 gallons ÷ 3) ÷ 500 bathers = 200 days

(900 gallons ÷ 3) ÷ 100 bathers = 3 days

Langelier Saturation Index

- Method of measuring the tendency of water to be corrosive or scaling
- Developed in 1936 by W.F. Langelier at UC Berkeley
- Formula expresses the relationship between pH, total alkalinity, calcium hardness, water temperature and dissolved solids
- Saturation index = pH + alkalinity factor + calcium factor + temperature factor - TDS factor
- If water is balanced, the formula will equal zero, with a plus or minus 0.3 tolerance
- Positive results indicate likely carbonate scale formation
- Negative results indicate corrosive tendencies

Langelier Saturation Index

SI = pH + Af + Cf + Tf - TDSf

Temp. F		Calcium Hardness		Total Alkalinity		TDS	
66	0.5	75	1.5	50	1.7	<1,000	12.1
77	0.6	100	1.6	75	1.9	>1,000	12.2
84	0.7	150	1.8	100	2.0		
94	0.8	200	1.9	150	2.2		
105	0.9	300	2.1	200	2.3		
		400	2.2	300	2.5		
		800	2.5	400	2.6		
		1000	2.6				

Langelier Saturation Index

SI = pH + af + cf + tf - TDSf

pH	7.7
Total Alkalinity	140 ppm
Calcium Hardness	300 ppm
Water Temperature	104° F
TDS	850 ppm

SI = 7.7 + 2.2 + 2.1 + .9 - 12.1 = +.8