CHAPTER 6

WATER CHEMISTRY AND POOL WATER BALANCE

LEARNING OBJECTIVES

After completely studying this chapter, you should be able to:

- Understand and list the parameters upon which water balance is based.
- Calculate if the pool water is "balanced," "scale-forming" or "aggressive/corrosive" using the Langelier Saturation Index.
- List problems associated with low pH and high pH pool water.
- Understand the relationship between pH and total alkalinity of the pool water.
- Explain how to lower total alkalinity in pool water.
- List the acceptable water quality ranges for total hardness, total alkalinity and total dissolved solids.
- Explain how over- and under-saturation affects water quality.

The pool operator must pay close attention to water chemistry parameters to control the chemical equilibrium of pool water. The **Langelier Saturation Index** for calculating saturation is used to determine if the pool water is under-saturated or over-saturated. **Under-saturated** water condition is commonly called corrosive or aggressive. When water is in an **over-saturated** condition, it is scale-forming.

It is the nature of water to dissolve the things with which it comes into contact, until it becomes saturated. When this happens, water loses this excess material (that which was dissolved) and the material will precipitate, or come out of solution. This over-saturated condition is called "scale forming."

Langelier Saturation Index

Stable water quality is based on proper use of the saturation index and formula. Bringing the pH, total alkalinity, total hardness, temperature, and total dissolved solids together using the index gives the pool operator the complete answer to pool water quality and balance.

Various factors are used to calculate saturation levels. The results provide the operator information needed to balance the pool and correct its corrosive or scale-forming condition.

First, the pool operator must test all parameters of the water chemistry with the appropriate test kits and then obtain the correct "factors" from Table 1. Next, the numerical values from Table 1 are substituted into the following formula:

SATURATION INDEX = pH + TF + CF + AF − 12.1

pH: measured from test kit (chapter 4)

TF: temperature factor, measured at pool

CF: calcium hardness, measured from test kit (chapter 4)

AF: alkalinity factor, measured at pool (chapter 4)

Water with a calculated index between:

-0.5 and 0.5 is *balanced.*

OVER

0.5 is *scale-forming* (over-saturated).

BELOW

-0.5 is *corrosive* (under-saturated).

Example:

A swimming pool has a F.A.C. of 2.0 ppm, total available chlorine (T.A.C.) residual of 2.5 ppm, with a pH of 7.0. The total alkalinity is 50 ppm and calcium hardness is 200 ppm; water temperature is 84° F. ***Is the pool water scale-forming?***

SATURATION INDEX = (pH) 7.0 + (TF) 0.7 + (CF) 1.9 + (AF) 1.7 − 12.1 = -0.8

In this equation we are given the pH of 7.0.

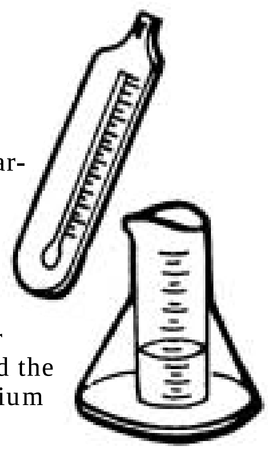
Table 1 shows that when:

- Water temperature is 84° F, the temperature factor (TF) is 0.7.
- Calcium hardness is 200 ppm the CF is 1.9.
- Alkalinity is 50 ppm, the AF is 1.7.

The equation solution equals -0.8. From the saturation index information above, this indicates a corrosive water condition.

Parameters for Saturation Index

Temperature



The higher the temperature of the pool water, the less soluble calcium carbonate becomes. In most cases water temperature cannot be kept constant due to unpredictable weather and environmental conditions. As a pool operator, be aware of this and monitor the temperature when other water parameters are checked. Keep in mind the influence temperature has on the calcium carbonate levels—warmer water, less soluble; colder water, more soluble.

pH

Accurate control of the pH of swimming pool water is essential. According to the Michigan Public Swimming Pools Act 368, swimming pool water must be maintained between 7.2 to 8.0. However, a pH range of 7.2 to 7.6 is more practical from a management standpoint. Simply stated, pH is a numerical value that indicates whether water is acid, basic, or neutral (see Chapter 3). The concentration of hydrogen ions determines the pH of water. The greater the hydrogen concentration the lower the pH. Pure distilled water has a pH of 7.0, which is considered neutral. Water with a pH of less than 7.0 is said to be acidic, and the smaller the number the more acidic the water. On the other hand, water with a pH greater than 7.0 is basic, the larger the number, the more basic the water. Healthy pools require that water is slightly basic. The optimum pH measurement for pool water is 7.2 – 7.6. pH plays two major roles in water chemistry—it buffers acidic disinfectants added to swimming pool water, and it plays the most significant role in the water balancing equation (Langelier Saturation Index).

To *decrease* the pH of pool water, either a granular acid (sodium bisulfate) or liquid acid (muriatic acid) is added. Sodium bisulfate ($NaHSO_4$) is an acid salt that is frequently used because it is relatively easy to handle. The white granular compound can be added by chemical feeder or by dissolving in water and then pouring directly into the pool.

Muriatic acid is the commercial grade of hydrochloric acid (HCl) that is also used for reducing pH of pool water. Muriatic acid is a corrosive acid that is relatively inexpensive, but requires extremely careful handling. Wear rubber gloves and safety glasses when handling

Table 1. Numerical values for saturation index formula.

WATER TEMP (°F)	TEMP. FACTOR TF	PPM $CaCO_3$	CALCIUM HARDNESS CF	TOTAL ALKALINITY AS PPM $CaCO_3$	ALKALINITY FACTOR AF
32	0.0	5	0.3	5	0.7
37	0.1	25	1.0	25	1.4
46	0.2	50	1.3	50	1.7
53	0.3	75	1.5	75	1.9
60	0.4	100	1.6	100	2.0
66	0.5	150	1.8	150	2.2
76	0.6	200	1.9	200	2.3
84	0.7	300	2.1	300	2.5
94	0.8	400	2.2	400	2.6
105	0.9	800	2.5	800	2.9
128	1.0	1000	2.6	1000	3.0

muriatic acid. Use caution when storing muriatic acid. If container lids do not fit tightly, fumes from the acid can cause damage to electrical equipment, heating equipment, and metal surfaces.

To *increase* the pool water pH to a more basic condition, adding soda ash (sodium carbonate) is recommended. One pound (16 ounces) of sodium carbonate per 10,000 gallons will raise pH 0.3. Add soda ash to the pool by dissolving the powder in water and feeding the solution through a chemical feeder, or dissolved it in a bucket and pour the solution directly into the pool water. Add soda ash when the pool is closed, preferably in the evening after is has closed for the day. See Chapter 3 for more information on pH management.

Failure to keep the pool water within the pH range of 7.2 – 7.6 can produce the following results:

Low pH (acidic)	**High pH (basic)**
Equipment destruction	Scale forming
Red eyes	Reduced Chlorine effectiveness
Hair loss	Plugged filtration system
Pool surfaces deteriorate	Irritation to users
Staining	Cloudy water
Cloudy water	
Scale removing	

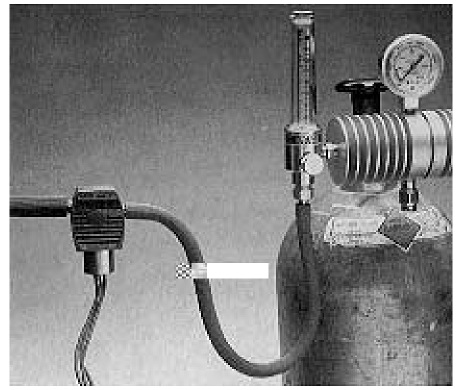
The pH level effects the ability of chlorine to sanitize pool water. The higher the pH, the lower the amount of hypochloric acid available to sanitize and oxidize the unwanted materials in pool water. (See Table 2.) Pool water pH has a similar effect on the effectiveness of bromine. See Chapter 3 for more details.

Table 2. Effect of pH on chlorine activity.

Hypochlorous Acid Chlorine as HOCl (Active) HOCl	pH	Hypochlorite Ion Chlorine as OCl (Inactive) OCl
90%	6.5	10%
73%	7.0	27%
66%	7.2	34%
45%	7.6	55%
21%	8.0	79%
10%	8.5	90%

Lowering pH with Carbon Dioxide (CO_2)

The use of carbon dioxide (CO_2) as an alternative to liquid and dry acids has recently become a popular method for lowering pH of pool water. When CO_2 is dissolved in water it forms a mild acid compound and reduces pH. While lowering pH, CO_2 also raises total alkalinity since it forms a bicarbonate salt. Because CO_2 increases total alkalinity of the water, it should not be used in pools where high alkalinity is a problem, since bicarbonate scale can form.



Calcium Carbonate ($CaCO_3$)

Calcium carbonate ($CaCO_3$) is a mineral present in all water, either naturally occurring in the water or introduced with the addition of chemicals to pool water. Calcium carbonate is the least soluble mineral found in water, and, therefore, it is the one mineral that becomes under-saturated. The degree of saturation by calcium carbonate is governed by pH, temperature, alkalinity, calcium hardness, and total dissolved solids. At higher temperatures, such as in spas or hot tubs, calcium carbonate becomes even less soluble. Controlling calcium carbonate is essential. Test kits are used to measure the ppm calcium carbonate available in the water.

Spas and hot tubs have greater water balancing demands than larger pools because of higher water temperatures and bather loads.

Under-saturated water is aggressive and has corrosive action against equipment, the pool structure, and swimmers' skin. Under-saturation damages pool walls, plumbing, and filtration system equipment. Brown, black, or green water, which contributes to surface stains on the pool walls, floor, and structure, is also characteristic of under-saturated water. This is caused by the under-saturated water attacking the metal components of the filtration system.

A symptom of over-saturation is scale formation—scale forms on the walls of the pool and on the insides of plumbing equipment. This may inhibit equipment performance and lead to equipment failure.

Total Alkalinity and Its Control

Total alkalinity is the measure of the pool's buffering capacity to resist pH change. Without complete control of the total alkalinity portion of the water chemistry, the pH will rise and fall abruptly. The ability to resist this change in pH is due to the presence of carbonate ions. There are other compounds that also provide some buffering.

The pool operator must control both the amount of carbonate alkalinity and the pH to provide enough calcium carbonate to saturate the water without having more than is required. With a desirable pH range of 7.2 – 7.6, most of the carbonate ions are in the bicarbonate form, which provides buffering and a small amount of carbonation.

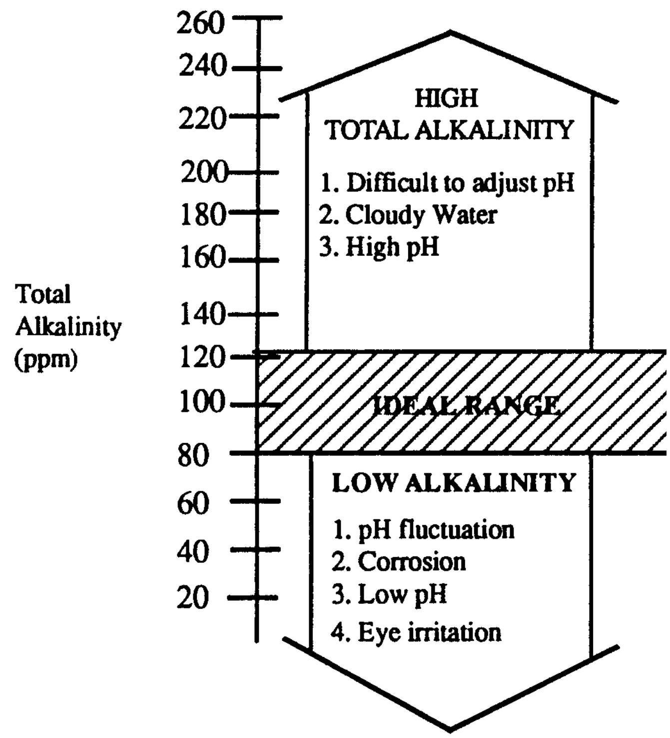
In general, total alkalinity must be kept between 80 ppm and 125 ppm, but pools with liners should be kept at 80-120 ppm, and plaster finished pools should have a total alkalinity of 100 – 125 ppm.

There are consequences when alkalinity is either too high or too low. Water with a low total alkalinity acts much like water with a low pH (aggressive), and water with a high total alkalinity acts much like a water with high pH (basic, scale-forming).

A low total alkalinity makes it difficult to maintain a desired pH, and can lead to corrosive water which causes damage to equipment. Green water is another symptom of low total alkalinity. To raise total alkalinity in pool water, add sodium bicarbonate. If the total alkalinity is less than 80 ppm, it can be raised approximately 10 ppm per 10,000 gallons of pool water by adding $1\frac{1}{2}$ pounds of sodium bicarbonate per 10,000 gallons of water until the desired level has been reached.

Higher levels of total alkalinity can cause "pH lock," which is what happens when the pH gets stuck at a certain level and is difficult to change. High total alkalinity can also cause scale to form and the water to become cloudy. To lower the total alkalinity, add sodium bisulfate or muriatic acid. This will also lower the pH. Locate the deepest part of the pool and, wearing protective gear, pour full strength muriatic acid into the water in a small area about the size of a basketball. The total alkalinity will "gas off" in this area, releasing CO_2, carbon dioxide. If during this application the pH is not lowered enough to form carbonate acid, no carbon-dioxide gas will escape and the total alkalinity will remain unchanged, but the pH will be lowered. With a larger pool, two or three areas may be lowered at one time. Several applications may be necessary. Repeat this procedure daily until the desired total alkalinity is obtained. Never add more than one quart of muriatic acid per 10,000 gallons of water.

If using sodium bisulfate, first mix with cool water and then apply to the pool in the same way as described for muriatic acid.



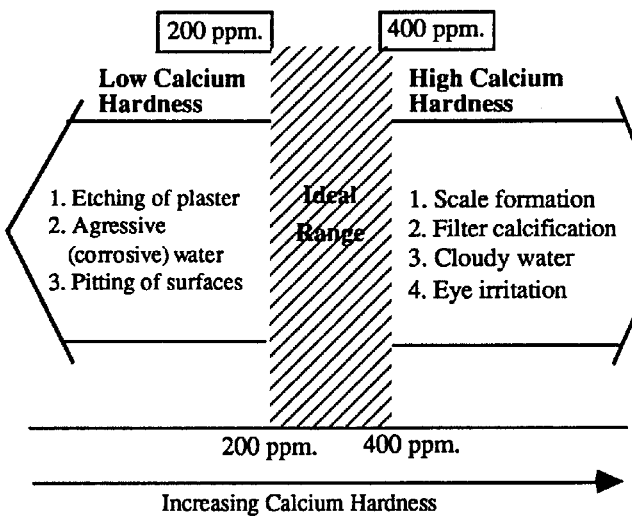
Total Hardness

Total hardness refers to water hardness. Calcium (Ca) and magnesium (Mg) are the primary ions contributing to water hardness with calcium accounting for 97% of the hardness. Other hardness contributors are iron (Fe) and aluminum (Al) but are generally ignored because they are easily removed in the water treatment process, or by the addition of sequestering agents. Swimming pools require hard water. Water with more than 100 ppm of hardness ions are called hard water.

Like pH and alkalinity, *calcium hardness* effects the tendency of pool water to be corrosive when it is low, and scale-forming when it becomes high. Only calcium ions combine with carbonate ions to form the calcium carbonates needed for water saturation. Therefore, as with pH and alkalinity, the pool operator must conduct tests for calcium hardness levels to determine the calcium factor (CF, which is used in the Langelier Saturation Index equation).

Generally, keep calcium hardness levels at 200 to 400 ppm. Generally, low calcium hardness presents a larger problem to pools than high calcium hardness does. If pH, total alkalinity, and calcium hardness are low, the corrosiveness and aggressiveness of the pool water will be greatly increased. This causes problems in deterioration of the pool walls and corrosion of metal parts. The calcium hardness values can be increased by adding *pharmaceutical grade* calcium chloride (not snow melter). Use 10 pounds of calcium chloride (80% $CaCl_2$) for each 10,000 gallons of water to raise the calcium chloride 80 ppm. Because calcium chloride produces a significant amount of heat, divide the total amount needed into two equal parts and apply to the pool in two applications.

While calcium hardness levels are typically maintained in the 200 to 400 ppm range they should not exceed 400-600 ppm, depending on the temperature and pH. If the calcium hardness reaches 600 ppm, make corrective adjustments. The exact values can be calculated using the Langelier Saturation Index. The only way to reduce excessively high levels of calcium hardness is to remove some of the pool water and replace it with fresh water. If the calcium hardness of your make-up water is high, water from another source may be necessary. Very often normal splash-out by swimmers and filter backwash procedures remove and replace enough water to maintain an acceptable calcium level. With high temperatures and excessive evaporation rates, additional water may have to be drained periodically to lower calcium hardness levels. Test for calcium hardness levels two to three times a month.



Total Dissolved Solids (TDS)

Nothing put into the pool water is one hundred percent soluble. Some chemicals react with water to form salt, while other chemicals stay in suspension. Others will form a light scale on pool surfaces, such as salt scale inside piping, or on the sand filter. The amount of material in suspension is referred to as total dissolved solids (TDS).

The National Swimming Pool Foundation suggests keeping the levels of TDS under 1500 ppm. With a TDS level of 2,000 ppm, the salt portion would be 17 pounds for every 1,000 gallons of water.As a comparison, salt water may have a TDS level of 35,000 ppm—350 pounds of salt for every 1,000 gallons of water!

All salt-like materials make balancing water chemistry difficult. It's like driving a car in heavy traffic—you know where to go but cannot get there because of all the obstacles in the way. When TDS are high, the pool water testing results will be erratic and unreliable and the water will look pale and cloudy. The only way to correct this problem is to dilute by adding fresh water.

Total dissolved solids can become so high that the pool and its components become saturated. This condition requires:

- Draining the pool,
- Scrubbing the walls and floors to remove the salt residue;
- Changing the filter sand;
- Replacing the filter cartridge or cleaning the earth elements.

Temperature

As water temperature increases, the water balance tends to become more basic and scale-forming. Conversely, as the temperature decreases, water becomes more corrosive. However, cince the temperature of pool water results from seasonal weather conditions or is selected to provide bather comfort, operators cannot adjust it to achieve saturation or balanced water. Due to temperature's effect on the corrosiveness or scale-forming properties of water, it is included as a factor in the Langelier Satruation Index (SI). Relatively speaking, however, temperature is the least significant factor affecting SI.

CHAPTER 6

Review Questions

Water Chemistry and Pool Water Balance

Write the answers to the following questions, then check your answers with those in the back of the manual.

1. What is the Langelier Saturation Index and what water characterisitc is it used to determine?

2. What parameters are involved in calculating the saturation index?

3. Using the Langelier Saturation Index, calculate if the pool water is either aggressive or scale-forming based on the following information:

   Swimming pool water has:

   - free available chlorine (F.A.C.) of 2.5 ppm,
   - total available chlorine (T.A.C.) of 3.0 ppm,
   - pH of 7.2,
   - total alkalinity is 75 ppm,
   - calcium hardness of 300 ppm,
   - temperature of 76° F.

4. Name 5 conditions that result from low pH (acidic) and 5 conditions from high pH water.

   Low pH-

   High pH-

5. How should muriatic acid be added to the pool?

6. How much undiluted muriatic acid would be used to lower the total alkalinity in a 50,000 gallon pool? (Add no more than 1 quart undiluted muriatic acid per 10,000 gallons of water.)

   a. 1 quart
   b. 2.5 quarts
   c. 5 quarts
   d. 10 quarts

7. What is the least soluble mineral found in water?

   a. Iron.
   b. Magnesium.
   c. Calcium carbonate.
   d. Aluminum.

8. Between what levels should the calcium hardness be maintained? Why?

   a. 50-200 ppm.
   b. 200-400 ppm.
   c. 400-600 ppm.
   d. 500-700 ppm.

9. What is the “salt-like material” that causes light scale to form on pool walls, inside piping, and on the filters?

   a. TDS (total dissolved solids).
   b. Algae.
   c. Soda ash.
   d. Filter sand.