1.

Calculation Forumulas (Imperial)

Amount Conversions	
Ounces to Pounds	Ounces ÷ 16 = Pounds
Fluid Ounces to Gallons	Fluid Ounces ÷ 128 = Gallons
Distance Conversions	
Yards to Feet	Yards x 3 = Feet
Meters to Feet	Meters x 3.28 = Feet
Surface Areas	
Radius = Diameter ÷ 2	
Rectangle/Square	Length x Width = Square Feet
Circle	3.14 x Radius x Radius = Square Feet
Pool Volume	
Average Depth = (shallow + deep) ÷ 2	
Rectangle	Length x Width x Average Depth x 7.5 = Gallons
Circle	3.14 x Radius x Radius x Avg. Depth x 7.5 = Gallons
Formulas	
Turnover Rate	Pool Volume ÷ Flow Rate ÷ 60 = Hours
Flow Rate	Pool Volume ÷ Turnover Rate ÷ 60 = Gallons/Minute (gpm)
Filter Surface Area	Flow Rate ÷ Filtering Rate = Square Feet
Heater Sizing	Pool Volume x 8.33 x Temperature Adjustment = BTU

Water Chemistry Guidelines

These commonly accepted chemical parameters do not supersede product label directions, local and state regulations.

Parameter	Min	Ideal	Max	Pool Type
Free Chlorine (ppm or mg/L)	1.0	2.0–4.0	5.0	Pools, Waterparks
	2.0	3.0–5.0	10.0	Spas
Combined Chlorine (ppm or mg/L)	0	0	0.4	Pools, Waterparks
	0	0	0.5	Spas
Total Bromine (ppm or mg/L)	2.0	4.0–6.0	10.0	All Types
PHMB (ppm or mg/L)	30	30–50	50	All Types
pH	7.2	7.4–7.6	7.8	All Types
Total Alkalinity as $CaCO_3$ (ppm or mg/L)	60	80-100* 100–120**	180	All Types
Total Dissolved Solids (ppm or mg/L)	NA	NA	1,500 over startup	All Types
Calcium Hardness as $CaCO_3$ (ppm or mg/L)	150	200–400	1,000	Pools, Waterparks
	100	150–250	800	Spas
Heavy Metals	None	None	None	All Types
Visible Algae	None	None	None	All Types
Bacteria	None	None	Local Code	All Types
Cyanuric Acid (ppm or mg/L)	****	30–50	****	All Types
Temperature °F/°C	78°F (25.5°C)	80.5°F (26.9°C)	82°F (27.8°C)	Competition Pools
	-	-	104°F (40°C)	Spas
	-	Personal Preference	104°F (40°C)	Other Pools
Ozone (ppm or mg/L)	-	-	0.1 over 8 hr time wtd. avg.	All Types
ORP	Calibrate to Disinfectant Level*****			All Types

* For calcium hypochlorite, lithium hypochlorite, or sodium hypochlorite
** For sodium dichlor, trichlor, chlorine, gas, BCDMH
*** Start-up includes the TDS contribution of salt found in chlorine generating systems
**** Dictated by local codes. Typically 100 ppm (mg/L). Some codes are higher, some are lower
***** Some local codes may dictate a minimum and maximum

replacement is a good management tool to use to maintain proper TDS levels in pools and spas. Some facilities develop a daily water replacement based on average user load. See the Spa & Therapy Operations chapter for more discussion concerning the water replacement interval.

Saturation Index

Wilfred F. Langelier, a professor of Civil Engineering at the University of California-Berkeley, developed a method of coating water distribution piping with a thin layer of scale. His published paper "The Analytical Control of Anti-Corrosive Water Treatment" quantified the corrosive potential of water. The index developed in this paper is called the Langelier Index.

The Langelier Index has been adopted by many industries and has spread to industrial water treatment as well as domestic drinking water treatment. The swimming pool industry developed a modified version of the Langelier Index in the 1970s. This index was adjusted for pool/spa water conditions and provides a method for determining whether the water is balanced with regard to calcium carbonate equilibrium.

The Saturation Index (SI) is a method of determining whether water will deposit calcium carbonate or maintain it in solution. The SI incorporates the five balance factors discussed in this chapter: pH, total alkalinity, calcium hardness, temperature, and total dissolved solids. Sequestering agents used to prevent scale, staining, or discoloration in water can improve the solubility characteristics of calcium carbonate, reducing the formation of scale. As a result, the balance point (0) of the SI can shift to a more positive number.

When higher cyanuric acid levels are present in water, the contribution of cyanuric acid should be removed from the total alkalinity since the saturation index uses the alkalinity due to carbonate, or total carbonate alkalinity, to determine the water balance. The cyanuric acid concentration should be divided by 3 to give the contribution to total alkalinity. For example, if the total alkalinity reading was 90 ppm (mg/L) and the cyanuric acid level is 60 ppm (mg/L), the total carbonate alkalinity would be 70 ppm (mg/L), since 20 ppm (mg/L) of the total alkalinity reading was due to the cyanuric acid interference (60 ppm (mg/L) ÷ 3 = 20 ppm (mg/L)).

Temperature, calcium hardness, total alkalinity, and total dissolved solids are expressed in the SI as factors Tf, Cf, Af, and TDSf respectively, as shown in Illustration 6-7. The pH of the water is substituted directly into the index.

For pool and spa waters, the ideal result of performing this index is to have a result of zero, i.e., SI = 0. Balanced water is between - 0.3 and + 0.5. Corrosive water is - 0.4 and lower. Scaling water is + 0.6 and higher.

Calculating the Saturation Index

To determine whether pool or spa water is properly balanced, a full water chemistry analysis is necessary. When calculating the SI, use the factors in Illustration 6-7. If an actual measurement is not found in the chart, use the next greatest value. The measured pH value is used directly in the formula. The Saturation Index formula is as follows:

SI = pH + Tf + Cf + Af – TDSf

If the water is not balanced, adjustments must be made to bring the water back into balance. The sequence of adding chemicals to make the adjustment should be total alkalinity first, followed by pH, and calcium hardness third. Temperature is not normally adjusted for water balance as most of the time it is not a controllable factor.

Example 6.1

Your pool water test readings are as follows:

pH	7.2
Temperature	84°F (28.9°C)
Calcium Hardness	200 ppm or mg/L
Total Alkalinity	100 ppm or mg/L
TDS	2,250 ppm or mg/L

Using the Saturation Index formula, the following results are obtained:

SI = pH + Tf + Cf + Af - TDSf
SI = 7.2 + 0.7 + 1.9 + 2.0 - 12.3
SI = - 0.5

The water is corrosive.

Example 6.2

Your spa water test readings are as follows:

pH	7.7
Temperature	104°F (40°C)
Calcium Hardness	400 ppm or mg/L
Total Alkalinity	100 ppm or mg/L
TDS	3,500 ppm or mg/L

Using the Saturation Index formula, the following results are obtained:

SI = pH + Tf + Cf + Af - TDSf
SI = 7.7 + 0.9 + 2.2 + 2.0 - 12.4
SI = + 0.4

The water is balanced.

Example 6.3

You can also use the following SI Worksheet in order to calculate the SI value for your pool water. Using the factors chart in Illustration 6-7, insert the factors values for each measured variable. Note that in this example the water is not balanced with a Saturation Index value of -0.5, which means that the water is corrosive. The values given in red are possible adjustments that can be made to bring the water back into balance. These adjustments are not the only ones that can be made to bring the water back into balance.

Saturation Index Factors

Temperature			Calcium Hardness expressed as $CaCO_3$		Total Carbonate Alkalinity	
°F	°C	Tf	ppm (mg/L)	Cf	ppm (mg/L)	Af
32	0.0	0.0	25	1.0	25	1.4
37	2.8	0.1	50	1.3	50	1.7
46	7.8	0.2	75	1.5	75	1.9
53	11.7	0.3	100	1.6	100	2.0
60	15.6	0.4	125	1.7	125	2.1
66	18.9	0.5	150	1.8	150	2.2
76	24.4	0.6	200	1.9	200	2.3
84	28.9	0.7	250	2.0	250	2.4
94	34.4	0.8	300	2.1	300	2.5
105	40.6	0.9	400	2.2	400	2.6
			800	2.5	800	2.9

Total Dissolved Solids Factors

TDS	Factor
≤800	12.1
801-1,500	12.2
1,501-2,900	12.3
2,901-5,500	12.4
>5,500	12.5

Illustration 6-7.

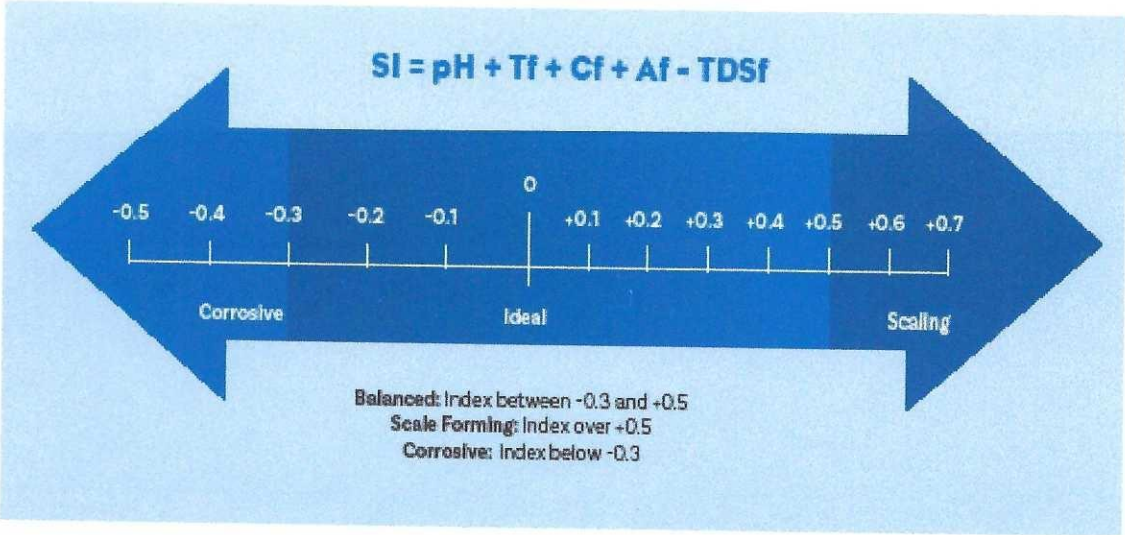

Illustration 6-8.

Saturation Index Factors

Temperature			Calcium Hardness expressed as $CaCO_3$		Total Carbonate Alkalinity	
°F	°C	Tf	ppm (mg/L)	Cf	ppm (mg/L)	Af
32	0.0	0.0	25	1.0	25	1.4
37	2.8	0.1	50	1.3	50	1.7
46	7.8	0.2	75	1.5	75	1.9
53	11.7	0.3	100	1.6	100	2.0
60	15.6	0.4	125	1.7	125	2.1
66	18.9	0.5	150	1.8	150	2.2
76	24.4	0.6	200	1.9	200	2.3
84	28.9	0.7	250	2.0	250	2.4
94	34.4	0.8	300	2.1	300	2.5
105	40.6	0.9	400	2.2	400	2.6
			800	2.5	800	2.9

Total Dissolved Solids Factors

TDS	Factor
≤800	12.1
801-1,500	12.2
1,501-2,900	12.3
2,901-5,500	12.4
>5,500	12.5

	Value	Factor	New Value	Factor
pH	7.4	+7.4	7.4	+7.4
Temperature	84°F (28.9°C)	+0.7	84°F (28.9°C)	+0.7
Calcium Hardness	100	+1.6	200	+1.9
Carbonate Alkalinity	75	+1.9	80	+2.0
Sub-Total		11.6		12.0
Total Dissolved Solids	500	12.1	500	-12.1
Saturation Index		-0.5		-0.1

Illustration 6-9. Saturation Index worksheet.

Ryznar Stability Index

The Ryznar Stability Index (RSI) is another saturation index that is used by some industry professionals to judge how to maintain calcium carbonate water balance and reduce metal corrosion. Like Langelier's Index, RSI estimates the degree to which calcium carbonate deposits, or scales, on surfaces or dissolves/corrodes calcium carbonate from a surface. Yet, the most common focus for use of the RSI is to minimize metal corrosion through calcium carbonate's providing a protective coating on the metal surface.

Chemical Table

CHEMICAL	AMOUNT	EFFECT ON 10,000 GALLONS
Chlorine Adjusters		
Gas Chlorine	1.3 ozs.	1 ppm
Calcium Hypochlorite	2.0 ozs.	1 ppm
Sodium Hypochlorite	10.7 fl. ozs.	1 ppm
Lithium Hypochlorite	3.8 oz	1 ppm
Dichloro-s-triazinetrione (62%)	2.1 oz	1 ppm
Dichloro-s-triazinetrione (56%)	2.4 oz	1 ppm
Trichloro-s-triazinetrione	1.5 oz	1 ppm
Sodium Thiosulfate	2.6 oz.	1 ppm
Sodium Sulfite	2.4 oz	1 ppm
Total Alkalinity Adjusters		
Sodium Carbonate	14 oz	10 ppm
Sodium Bicarbonate	1.4 lbs.	10 ppm
Sodium Sesquicarbonate	1.25 lbs	10 ppm
Muriatic Acid (31.4%)	26 fl. ozs.	10 ppm
Sodium Bisulfate	2.1 lbs	10 ppm
Calcium Hardness Adjusters		
Calcium Chloride (100%)	0.9 lbs	10 ppm
Calcium Chloride (77%)	1.2 lbs	10 ppm
Stabilizer Adjusters		
Cyanuric Acid	13 oz	10 ppm

TDS	Factor
≤ 800	12.1
801-1,500	12.2
1,501-2,900	12.3
2,900-5,500	12.4
>5,500	12.5

Saturation Index

Temperature			Calcium Hardness		Total Alkalinity	
F	C	TF	ppm (mgL)	CF	ppm (mgL)	AF
32	0.0	0.0	25	1.0	25	1.4
37	2.8	0.1	50	1.3	50	1.7
46	7.8	0.2	75	1.5	75	1.9
53	11.7	0.3	100	1.6	100	2.0
60	15.6	0.4	125	1.7	125	2.1
66	18.9	0.5	150	1.8	150	2.2
76	24.4	0.6	200	1.9	200	2.3
84	28.9	0.7	250	2.0	250	2.4
94	34.4	0.8	300	2.1	300	2.5
105	40.6	0.9	400	2.2	400	2.6
			800	2.5	800	2.9

POOL & HOT TUB ALLIANCE

SATURATION INDEX WORKSHEET

	Value	Factor	New Value	Factor
pH				
Temperature				
Calcium Hardness				
Carbonate Alkalinity				
Sub-Total				
Total Dissolved Solids				
Saturation Index				

* *

	Value	Factor	New Value	Factor
pH				
Temperature				
Calcium Hardness				
Carbonate Alkalinity				
Sub-Total				
Total Dissolved Solids				
Saturation Index				

Chemical Adjustment Worksheet (Imperial)

Amount of Chemical (from product label)	Actual Pool Volume	Desired Chemical Change	Total
↓			
↓	÷ 10,000 gal (from product label or Appendix B-2) ↓	÷________ppm (from product label or Appendix B-2) ↓	
↓	x	x	=

Amount of Chemical (from product label)	Actual Pool Volume	Desired Chemical Change	Total
↓			
↓	÷ 10,000 gal (from product label or Appendix B-2) ↓	÷________ppm (from product label or Appendix B-2) ↓	
↓	x	x	=

Amount of Chemical (from product label)	Actual Pool Volume	Desired Chemical Change	Total
↓			
↓	÷ 10,000 gal (from product label or Appendix B-2) ↓	÷________ppm (from product label or Appendix B-2) ↓	
↓	x	x	=

Breakpoint Chlorination Worksheet (Imperial)

Step 1. Total Chlorine - Free Chlorine = Combined Chlorine

Step 2. Combined Chlorine x 10 - Existing FC = Adjustment

Step3. Use Chemical adjustment worksheet below

Amount of Chemical (from product label)	Actual Pool Volume	Desired Chemical Change	Total
	÷ 10,000 gal (from product label or Appendix B-2)	÷_____ppm (from product label or Appendix B-2)	
↓	x	x	=

Amount of Chemical (from product label)	Actual Pool Volume	Desired Chemical Change	Total
	÷ 10,000 gal (from product label or Appendix B-2)	÷_____ppm (from product label or Appendix B-2)	
↓	x	x	=

Calculations Homework (Imperial)

10.

1. What is the surface area of a circular spa with a 12 foot diameter?
2. What is the volume of a circular spa with a 12 foot diameter and a constant depth of 3.5 feet?
3. What is the surface area of a rectangular pool with a length of 105 feet and a width of 45 yards?
4. What is the volume of a rectangular pool with a length of 46 feet, a width of 24 feet, and a depth ranging from 4 feet in the shallow end to 8 feet in the deep end?
5. What is the surface area of a rectangular pool with a length of 75 yards and a width of 50 feet?
6. What is the volume of a rectangular pool with a length of 75 feet, a width of 50 feet, and a depth ranging from 3.5 feet in the shallow end to 12 feet in the deep end?
7. Calculate the Saturation Index for water that has a total alkalinity of 100 ppm, a pH of 7.3, a calcium hardness of 250 ppm, a temperature of 67°F, and a total dissolved solids of 1500 ppm. If it is not balanced, fix it.
8. Calculate the Saturation Index for water that has a total alkalinity of 100 ppm, a pH of 8.2, a calcium hardness of 200 ppm, a temperature of 78°F, and a total dissolved solids of 500 ppm. If it is not balanced, fix it.
9. Calculate the Saturation Index for water that has a total alkalinity of 70 ppm, a pH of 7.2, a calcium hardness of 200 ppm, a temperature of 77°F, and a total dissolved solids of 500 ppm. If it is not balanced, fix it.
10. Adjust the ALKALINITY from 70 ppm to 100 ppm in a 250,000 gallon pool using sodium bicarbonate.
11. An L-shaped pool is 175 feet long and 50 feet wide with a diving well 25 feet by 25 feet. How many gallons of water are lost each week if this pool loses ¼ inch per day due to evaporation and an additional 1 inch per week due to backwash and a leak?
12. Adjust the CALCIUM HARDNESS from 75 ppm to 150 ppm in a 150,000 gallon pool. Use Calcium Chloride 77%.
13. How much CYANURIC ACID is needed to raise the stabilizer level in a 75,000 gallon pool from 0 to 30 ppm?
14. How much CALCIUM HYPOCHLORITE is needed to breakpoint chlorinate a 125,000 gallon pool if the combined chlorine is 0.4 ppm, and free chlorine is 1.0 ppm?
15. An accidental fecal release occurs in a pool. The state health department requires raising the free chlorine level from 4 ppm to 20 ppm for 20 hours. How many gallons of sodium hypochlorite would be needed for an 80,000 gallon pool?
16. What is the turnover rate of a 3500 gallon commercial spa that has a flow rate of 150 gpm?
17. What is the flow rate of a 3500 gallon spa based on a 30 minute turnover rate?
18. A D.E. filter has eight elements each measuring 2.5 feet by 9 inches wide. What is the square footage of this filter?
19. A sand filter is 5 feet in diameter and 3 feet in depth. How much filter surface area does this filter have?
20. A 275,000 gallon pool needs to turn over the water every 8 hours. What flow rate is required for this turnover rate?
21. A pool with a sand filter system has a flow rate of 220 gpm and an optimal media flow rate of 12 gpm per square foot of filter medium. What is the required square feet of filter area to meet this need?

APPENDIX Q
Calculations Homework Answers

11.

1. Surface area = 6 x 6 x 3.14 = 113 square feet
2. Volume = 6 x 6 x 3.14 x 3.5 x 7.5 = ~2,967 gallons
3. Surface area = 105 x (45 yards x 3 = 135 feet) = 14,175 square feet
4. Volume = 46 x 24 x 6 x 7.5 = 49,680 gallons
5. Surface area = (75 yards x 3 = 225 feet) x 50 feet = 11,250
6. Volume = 75 x 50 x 7.75 (average depth) x 7.5 = ~217,969 gallons
7. Within ideal range

pH	7.3	7.3
Temperature	67	0.6
Alkalinity	100	2.0
Calcium Hardness	250	2.0
TDS	1500	-12.2
Saturation Index		-0.03

8. Scale forming: add acid a little at a time frequently to not drop total alkalinity too drastically

pH	8.2	8.2
Temperature	78	0.7
Alkalinity	100	2.0
Calcium Hardness	200	1.9
TDS	500	-12.1
Saturation Index		0.7

9. Corrosive: balance by raising alkalinity as well as calcium

pH	7.2	7.2
Temperature	77	0.7
Alkalinity	70	1.9
Calcium Hardness	200	1.9
TDS	500	-12.1
Saturation Index		-0.4

10. 1.4 pounds x 3 x 25 = 105 pounds of alkalinity needed to raise from 70 ppm to 100 ppm in a 250,000 gallon pool
11. 175 x 50 = 8,750 + (25 x 25 = 625) = 9,375 square feet x 2.75 x 0.0833 x 7.5 = ~16,107 gallons

APPENDIX Q
Calculations Homework Answers (cont'd)

12.

12. 1.2 pounds x 7.5 x 15 = 135 pounds

13. 13 ounces x 3 x 7.5 = 292.5 ounces ÷ 16 = 18 or 19 pounds

14. 0.4 combined chlorine x 10 = 4 ppm – 1 ppm (FC) = 3 ppm x 2 ounces x 12.5 = 75 ounces ÷ 16 = 4.7 pounds

15. 10.7 ounces x 16 x 8 = 1369.6 ÷ 128 = 10.7 grids

16. 3,500 ÷ 150 gpm ÷ 60 = 0.388 hours

17. FR = 3,500 ÷ 30 minutes = 116.6 gpm

18. To find D.E square footage: 8 (elements) x 2.5 feet x 0.75 (9 inches) x 2 (sides) = 30 square feet

19. To find the sand filter surface area: 2.5 x 2.5 x 3.14 = 19.63 square feet

20. Flow rate = 275,000 ÷ (8 x 60 = 480) = 573 gpm

21. FA = FR ÷ FMR FA = 220 gpm ÷ 12 gpm per square foot FA = 18.33 square feet