Standard Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis[1]

This standard is issued under the fixed designation D3739; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the calculation and adjustment of the Langelier saturation index for the concentrate stream of a reverse osmosis device. This index is used to determine the need for calcium carbonate scale control in the operation and design of reverse osmosis installations. This practice is applicable for concentrate streams containing xx 10 to 10 000 mg/L of total dissolved solids. For concentrate containing over 10 000 mg/L see Practice D4582.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D511 Test Methods for Calcium and Magnesium In Water
D1067 Test Methods for Acidity or Alkalinity of Water
D1129 Terminology Relating to Water
D1293 Test Methods for pH of Water
D1888 Methods Of Test for Particulate and Dissolved Matter in Water (Withdrawn 1989)[3]
D4194 Test Methods for Operating Characteristics of Reverse Osmosis and Nanofiltration Devices
D4195 Guide for Water Analysis for Reverse Osmosis and Nanofiltration Application
D4582 Practice for Calculation and Adjustment of the Stiff and Davis Stability Index for Reverse Osmosis
D6161 Terminology Used for Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis Membrane Processes

3. Terminology

3.1 *Defintions*—For definitions of terms used in this practice, refer to Terminology D1129 and Terminology D6161.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 For descriptions of terms relating to reverse osmosis, refer to Test Methods D4194.

3.2.2 *Langelier Saturation Index*—an index calculated from total dissolved solids, calcium concentration, total alkalinity, pH, and solution temperature that shows the tendency of a water solution to precipitate or dissolve calcium carbonate.

4. Summary of Practice

4.1 This practice consists of calculating the Langelier Saturation Index for a reverse osmosis concentrate stream from the total dissolved solids, calcium ion content, total alkalinity, pH, and temperature of the feed solution, and the recovery of the reverse osmosis system.

4.2 This practice also presents techniques to lower the Langelier Saturation Index by decreasing the recovery, by decreasing the calcium content of the feedwater, or by changing the ratio of total alkalinity to free carbon dioxide in the feedwater.

5. Significance and Use

5.1 In the design and operation of reverse osmosis installations, it is important to predict the calcium carbonate scaling properties of the concentrate stream. Because of the increase in total dissolved solids in the concentrate stream and the difference in passages for calcium ion, bicarbonate ion, and free CO_2, the calcium carbonate scaling properties of the concentrate stream will generally be quite different from those of the feed solution. This practice permits the calculation of the Langelier Saturation Index for the concentrate stream from the feed water analyses and the reverse osmosis operating parameters.

5.2 A positive Langelier Saturation Index indicates the tendency to form a calcium carbonate scale, which can be

[1] This practice is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.08 on Membranes and Ion Exchange Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

damaging to reverse osmosis performance. This practice gives various procedures for the adjustment of the Langelier saturation index.

5.3 The tendency to form $CaCo_3$ scale can be suppressed by the addition of antiscalents or crystal modifiers. Suppliers of antisealents and crystal modifiers can provide information on the scale inhibition peformance of these types of chemical. Their use may be appropriate for reducing scale formation in RO systems. The RO system supplier should be consulted prior to the use of antisealents and crystal modifiers to ensure they will not have a negative impact on the RO system.

6. Procedure

6.1 Determine the calcium concentration in the feed solution in accordance with Test Methods D511 and express as $CaCO_3$ as demonstrated in 6.6.

6.2 Determine the total dissolved solids of the feed solution using Methods of Test D1888.

6.3 Determine the total alkalinity of the feed solution using Test Methods D1067, and express as $CaCO_3$.

6.4 Measure the pH of the feed solution using Test Methods D1293.

6.5 Measure the temperature of the feed solution.

6.6 Convert feed water alkalinity and calcium as mg/L $CaCO_3$:

$$Ca_f = [Ca^{+2}] \times \frac{100gCaCo_3}{mol} \times \frac{1000mg}{g} \times \frac{1eqCaCO_3}{1eqCa^{+2}} \quad (1)$$

$$Alk_f = [HCO_3^-] \times \frac{100gCaCO_3}{mol} \times \frac{1000mg}{g} \times \frac{1eqCaCO_3}{2eqHCO_3^-} \quad (2)$$

where:

Ca_c = calcium concentration in concentrate as $CaCO_3$, mg/L,
Ca_f = calcium concentration in feed as $CaCO_3$, mg/L,
Alk_c = alkalinity in concentrate as $CaCO_3$, mg/L, and
Alk_f = alkalinity in feed as $CaCO_3$, mg/L.

6.7 Measure the concentration of all major ions using the methods cited in Guide D4195. At a minimum, measure the concentration of Mg^{++}, Na^+, K^+, $SO_4^=$, and Cl^-.

7. Calculation

7.1 Calculate the calcium concentration in the concentrate stream from the calcium concentration in the feed solution, the recovery of the reverse osmosis system, and the calcium ion passage as follows:

$$Ca_c = Ca_f \times \frac{1 - Y(SP_{Ca})}{1 - Y} \quad (3)$$

where:

Ca_c = calcium concentration in concentrate, as $CaCO_3$, mg/L,
Ca_f = calcium concentration in feed, as $CaCO_3$, mg/L,
Y = recovery of the reverse osmosis system, expressed as a decimal, and
SP_{Ca} = calcium ion passage, expressed as a decimal.

NOTE 1—SP_{ca} can be obtained from the supplier of the specific reverse osmosis system. For most reverse osmosis devices SP_{ca} can be considered to be zero, in which case the equation simplifies to:

$$Ca_c = Ca_f \times (1/1 - Y) \quad (4)$$

This assumption will introduce only a small error.

7.2 Calculate the total dissolved solids (TDS) in the concentrate stream from the total dissolved solids in the feed solution, the recovery of the reverse osmosis system, and the passage of total dissolved solids as follows:

$$TDS_c = TDS_f \times \frac{1 - Y(SP_{TDS})}{1 - Y} \quad (5)$$

where:

TDS_c = concentration of total dissolved solids in concentrate, mg/L,
TDS_f = concentration of total dissolved solids in the feed, mg/L,
Y = recovery of the reverse osmosis system, expressed as a decimal, and
SP_{TDS} = passage of total dissolved solids, expressed as a decimal.

NOTE 2—SPTDS can be obtained from the supplier of the specific reverse osmosis system. For most reverse osmosis devices SPTDS can be assumed to be zero, in which case the equation simplifies to:

$$TDS_c = TDS_f \times (1/1 - Y) \quad (6)$$

The error introduced will usually be negligible.

7.3 Calculate the alkalinity in the concentrate stream from the alkalinity in the feed solution, the recovery of the reverse osmosis system, and the passage of alkalinity, by:

$$Alk_c = Alk_f \times \frac{1 - Y(SP_{alk})}{1 - Y} \quad (7)$$

where:

Alk_c = alkalinity in concentrate, as $CaCO_3$, mg/L,
Alk_f = alkalinity in feed, as $CaCO_3$, mg/L,
Y = recovery of the reverse osmosis system, expressed as a decimal, and
SP_{alk} = alkalinity passage, expressed as a decimal.

NOTE 3—SP_{alk} is dependent on the pH of the feed solution and its value should be obtained from the supplier of the specific reverse osmosis system.

7.4 Calculate the free carbon dioxide content (C) in the concentrate stream by assuming that the CO_2 concentration in the concentrate is equal to the CO_2 concentration in the feed: $C_c = C_f$. The concentration of free carbon dioxide in the feed solution is obtained from Fig. 1 as a function of the alkalinity, temperature, and the pH of the feed solution.

$$C_c = 0.03742 \times Ln(TDS_c) - 0.0209 \times Temp + 2.5 \quad (8)$$

7.4.1 Calculate the pH of the concentrate stream (pH_c) using the ratio of alkalinity (from 7.3) to free CO_2 in the concentrate (from 7.4), Fig. 1, or use Eq 9.

$$pHc = 0.423 \times Ln\,(Alk_c/CO_{2c}) \quad (9)$$

7.4.2 Calculate CO_{2f} assuming $CO_{2c} = CO_{2f}$:

$$Co_{2f} = Alk_f \times exp - \left(\frac{(pH_f - 6.3022)}{0.423}\right) = CO_{2c} \quad (10)$$

7.5 From Fig. 2 obtain: pCa as a function of Ca_c, pAlk as a function of Alk_c, or use Eq 8, Eq 11, and Eq 12.

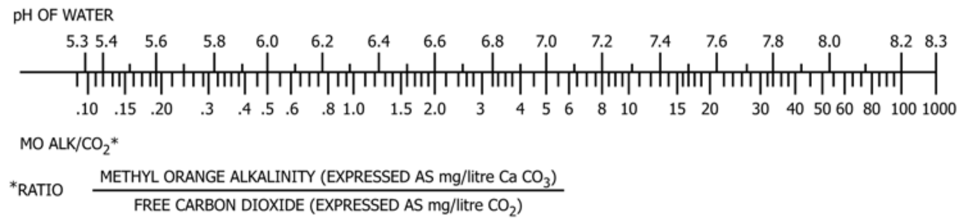

FIG. 1 pH Versus Methyl Orange Alkalinity/Free CO_2

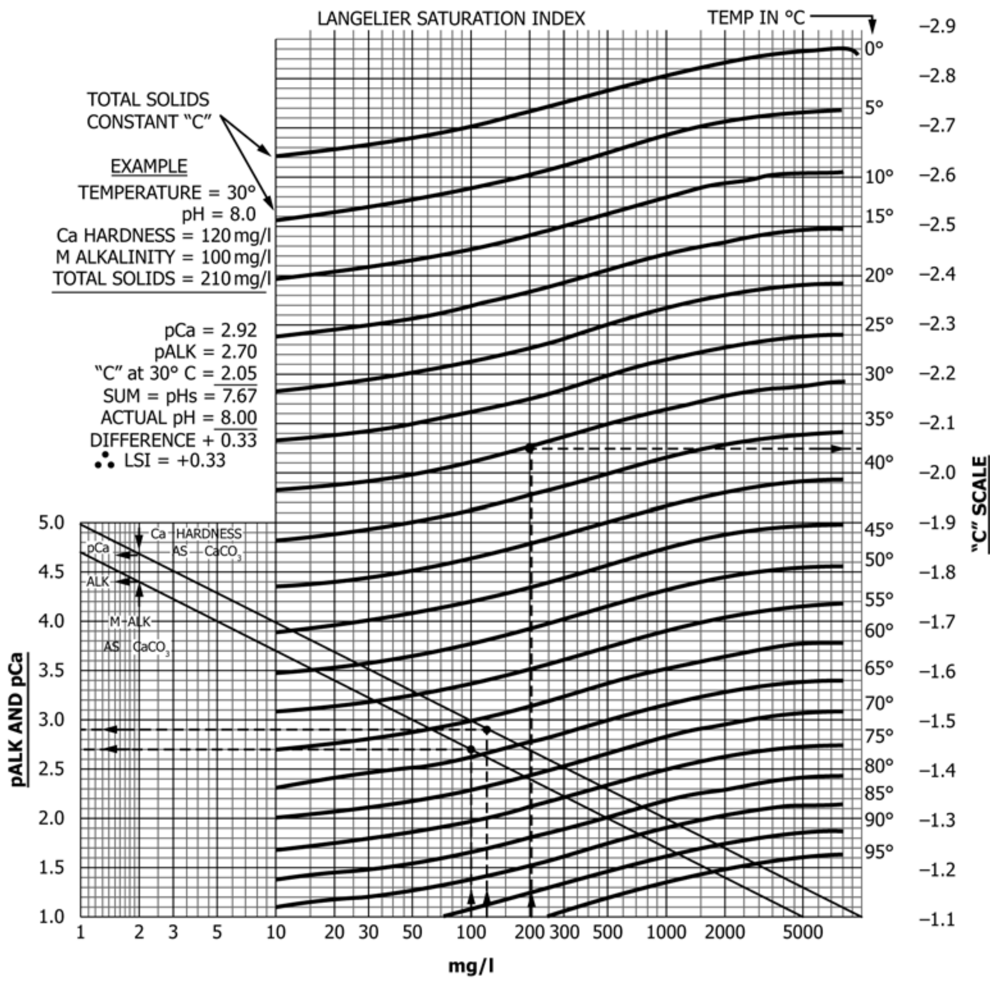

FIG. 2 Langelier Saturation Index

NOTE 4—Temperature of concentrate is assumed equal to temperature of feed solution.

$$pCa_c = -0.4343 \times Ln(Ca_c) + 5 \quad (11)$$

$$pAlk_c = -0.45 \times Ln(Alk_c) + 4.8 \quad (12)$$

7.6 Calculate pH at which concentrate stream is saturated with $CaCO_3$ (pH_s) as follows:

$$pH_s = pCa + pAlk + \text{"}C\text{"} \quad (13)$$

7.7 Calculate the Langelier Saturation Index of the concentrate (LSI_c) as follows:

$$LSI_c = pH_c - pH_s \quad (14)$$

8. Adjustments of LSI_c

8.1 If the LSI_c is unacceptable based on the supplier's recommendation, adjustments can be made by one of the following means. A new LSI_c can then be calculated.

8.1.1 The recovery (Y) can be lowered and the LSI_c can be calculated as above by substituting a new value for the recovery.

8.1.2 Decreasing the calcium concentration in the feed solution by means of sodium cycle ion exchange (softening) will increase the pCa and will therefore decrease the LSI_c. Softening will not change the alkalinity or pH of the feed solution and the slight change in TDS_f may be considered negligible. After softening, the LSI_c can be calculated as above using the lower value for calcium concentration.

8.1.3 Adding acid (HCl, CO_2, H_2SO_4, etc.) to the feed solution changes the Alk_f, C_f, pH, and SP_{alk}. The slight change in TDS_f can usually be neglected. Acid addition will decrease the LSI_c; however, since many variables change with acidification, trial and error computations are required to determine the amount of acid needed to obtain the desired LSI_c. The number of trial and error computations required to determine the amount of acid needed can be reduced greatly by using the pH_s calculated in 7.6. Since pH_c will usually be 0.5 units higher than the pH_f, the first computation can be made with an acidified feed solution which is 0.5 unit lower than the pH_s calculated in 7.6.

8.1.3.1 For an assumed pH (pH_{acid}), obtained from addition of acid to the feed solution, obtain the ratio of Alk_{acid}/C_{acid} from Fig. 1. From this ratio, Alk_f, and C_f calculate the milligrams per litre of acid used (*x*). For example, for H_2SO_4 addition (100 %):

$$\frac{Alk_{acid}}{C_{acid}} = \frac{Alk_f - 1.02x}{C_f + 0.90x} \tag{15}$$

8.1.3.2 Calculate the total alkalinity of the acidified feedwater (Alk_{acid}) and the CO_2 content in the acidified feedwater (C_{acid}) as follows:

$$Alk_{acid} = Alk_f - 1.02x \tag{16}$$

$$C_{acid} = C_f + 0.90x \tag{17}$$

8.1.3.3 Using Alk_{acid}, C_{acid}, and the supplier's value for SP_{alk} for the new pH, calculate the LSI_c in accordance with Section 7.

8.1.3.4 If HCl (100 %) is used for acidification, the Eq 15 is:

$$\frac{Alk_{acid}}{C_{acid}} = \frac{Alk_f - 1.37y}{C_f + 1.21y} \tag{18}$$

where:

y = HCI (100%), mg/L.

9. Reverse Osmosis in Operation

9.1 Once a reverse osmosis system is operating, the Langelier Saturation Index can be directly calculated from the analysis of Alk_c, Ca_c, TDS_c, and pH_c of the concentrate stream and compared with the projected LSI_c calculated in Section 7.

10. Keywords

10.1 $CaCO_3$ scale; Langelier Saturationndex; LSI; reverse osmosis; scaling