



## Standard Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis<sup>1</sup>

This standard is issued under the fixed designation D 3739; 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 up to 10 000 mg/L of total dissolved solids.

1.2 *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:

D 511 Test Methods for Calcium and Magnesium in Water<sup>2</sup>

D 1067 Test Methods for Acidity or Alkalinity of Water<sup>2</sup>

D 1129 Terminology Relating to Water<sup>2</sup>

D 1293 Test Method for pH of Water<sup>2</sup>

D 1888 Test Methods for Particulate and Dissolved Matter in Water<sup>3</sup>

D 4194 Test Methods for Operating Characteristics of Reverse Osmosis Devices<sup>4</sup>

### 3. Terminology

3.1 For definitions of terms used in this practice, refer to Terminology D 1129.

#### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 For descriptions of terms relating to reverse osmosis, refer to Test Methods D 4194.

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<sub>2</sub>, 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 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<sub>3</sub> scale can be suppressed by the addition of antisealents or crystal modifiers. Suppliers of antisealents and crystal modifiers can provide information on the scale inhibition performance 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.

<sup>1</sup> 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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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 11.01.

<sup>3</sup> Discontinued—See 1989 *Annual Book of ASTM Standards*, Vol 11.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 11.02.

## 6. Procedure

6.1 Determine the calcium concentration in the feed solution in accordance with Test Methods D 511 and express as  $\text{CaCO}_3$ .

6.2 Determine the total dissolved solids of the feed solution using Test Methods D 1888.

6.3 Determine the total alkalinity of the feed solution using Test Methods D 1067, and express as  $\text{CaCO}_3$ .

6.4 Measure the pH of the feed solution using Test Method D 1293.

6.5 Measure the temperature of the feed solution.

## 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:

$$\text{Ca}_c = \text{Ca}_f \times \frac{1 - Y(\text{SP}_{\text{Ca}})}{1 - Y} \quad (1)$$

where:

- $\text{Ca}_c$  = calcium concentration in concentrate, as  $\text{CaCO}_3$ , mg/L,
- $\text{Ca}_f$  = calcium concentration in feed, as  $\text{CaCO}_3$ , mg/L,
- $Y$  = recovery of the reverse osmosis system, expressed as a decimal, and
- $\text{SP}_{\text{Ca}}$  = calcium ion passage, expressed as a decimal.

NOTE 1— $\text{SP}_{\text{Ca}}$  can be obtained from the supplier of the specific reverse osmosis system. For most reverse osmosis devices  $\text{SP}_{\text{Ca}}$  can be considered to be zero, in which case the equation simplifies to:

$$\text{Ca}_c = \text{Ca}_f \times (1/1 - Y) \quad (2)$$

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:

$$\text{TDS}_c = \text{TDS}_f \times \frac{1 - Y(\text{SP}_{\text{TDS}})}{1 - Y} \quad (3)$$

where:

- $\text{TDS}_c$  = concentration of total dissolved solids in concentrate, mg/L,
- $\text{TDS}_f$  = concentration of total dissolved solids in the feed, mg/L,

- $Y$  = recovery of the reverse osmosis system, expressed as a decimal, and
- $\text{SP}_{\text{TDS}}$  = passage of total dissolved solids, expressed as a decimal.

NOTE 2— $\text{SP}_{\text{TDS}}$  can be obtained from the supplier of the specific reverse osmosis system. For most reverse osmosis devices  $\text{SP}_{\text{TDS}}$  can be assumed to be zero, in which case the equation simplifies to:

$$\text{TDS}_c = \text{TDS}_f \times (1/1 - Y) \quad (4)$$

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:

$$\text{Alk}_c = \text{Alk}_f \times \frac{1 - Y(\text{SP}_{\text{alk}})}{1 - Y} \quad (5)$$

where:

- $\text{Alk}_c$  = alkalinity in concentrate, as  $\text{CaCO}_3$ , mg/L,
- $\text{Alk}_f$  = alkalinity in feed, as  $\text{CaCO}_3$ , mg/L,
- $Y$  = recovery of the reverse osmosis system, expressed as a decimal, and
- $\text{SP}_{\text{alk}}$  = alkalinity passage, expressed as a decimal.

NOTE 3— $\text{SP}_{\text{alk}}$  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  $\text{CO}_2$  concentration in the concentrate is equal to the  $\text{CO}_2$  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 and the pH of the feed solution.

7.5 Calculate the pH of the concentrate stream ( $\text{pH}_c$ ) using the ratio of alkalinity (from 7.3) to free  $\text{CO}_2$  in the concentrate (from 7.4), Fig. 1.

7.6 From Fig. 2 obtain:  $p\text{Ca}$  as a function of  $\text{Ca}_c$ ,  $p\text{Alk}$  as a function of  $\text{Alk}_c$ , "C" as a function of  $\text{TDS}_c$  and temperature.

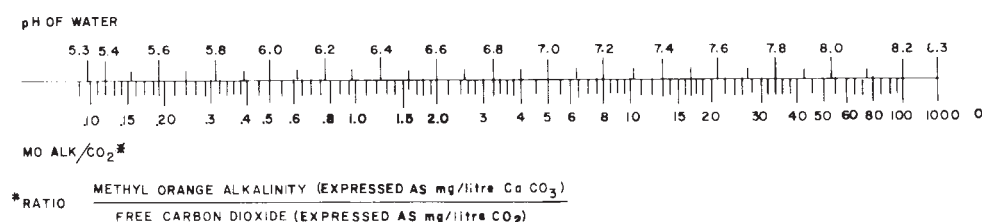
NOTE 4—Temperature of concentrate is assumed equal to temperature of feed solution.

7.7 Calculate pH at which concentrate stream is saturated with  $\text{CaCO}_3$  ( $\text{pH}_s$ ) as follows:

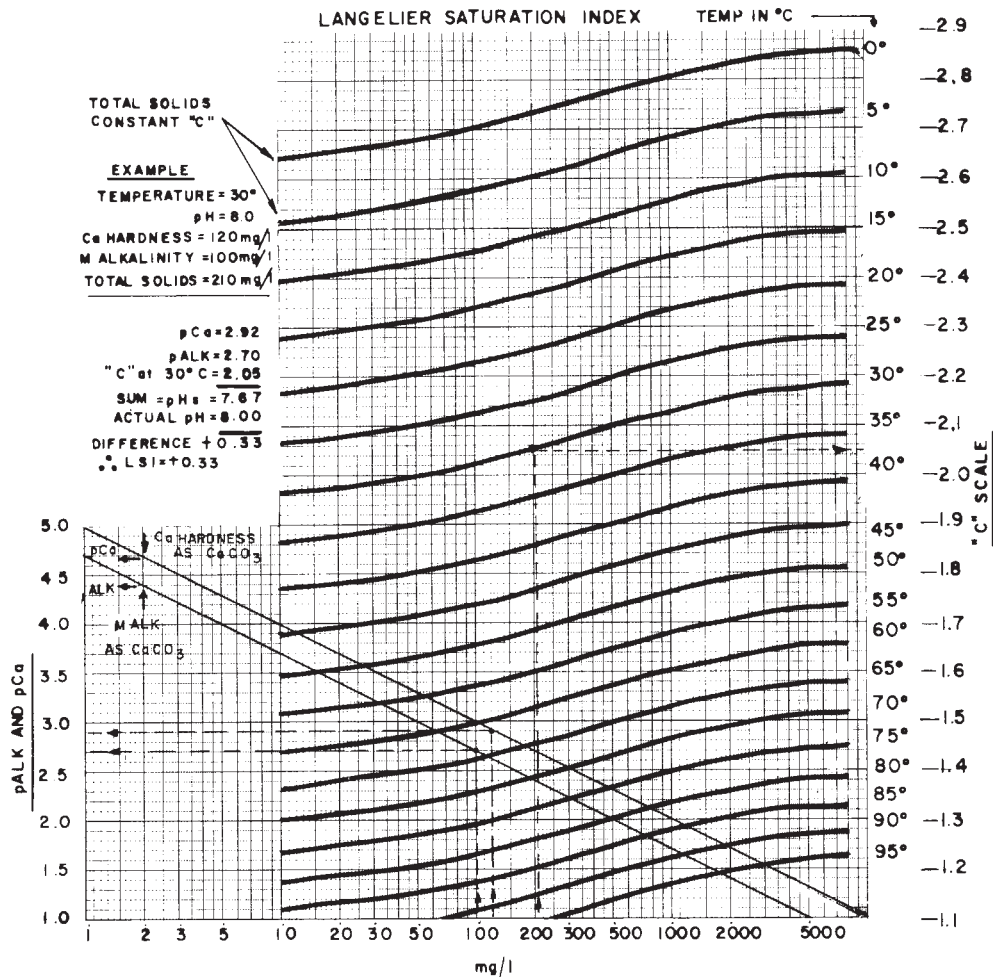
$$\text{pH}_s = p\text{Ca} + p\text{Alk} + "C" \quad (6)$$

7.8 Calculate the Langelier saturation index of the concentrate ( $\text{LSI}_c$ ) as follows:

$$\text{LSI}_c = \text{pH}_c - \text{pH}_s \quad (7)$$



**FIG. 1 pH Versus Methyl Orange Alkalinity/Free  $\text{CO}_2$**



## 8. Adjustments of LSI<sub>c</sub>

8.1 If the LSI<sub>c</sub> is unacceptable based on the supplier's recommendation, adjustments can be made by one of the following means. A new LSI<sub>c</sub> can then be calculated.

8.1.1 The recovery (Y) can be lowered and the LSI<sub>c</sub> 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<sub>c</sub>. Softening will not change the alkalinity or pH of the feed solution and the slight change in TDS<sub>f</sub> may be considered negligible. After softening, the LSI<sub>c</sub> can be calculated as above using the lower value for calcium concentration.

8.1.3 Adding acid (HCl, CO<sub>2</sub>, H<sub>2</sub>SO<sub>4</sub>, etc.) to the feed solution changes the Alk<sub>f</sub>, C<sub>f</sub>, pH, and SP<sub>alk</sub>. The slight change in TDS<sub>f</sub> can usually be neglected. Acid addition will decrease the LSI<sub>c</sub>; 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<sub>c</sub>. The number of trial and error computations required to determine the amount of acid needed can be reduced greatly by using the pH<sub>s</sub> calculated in 7.7. Since pH<sub>c</sub> will usually be 0.5 units higher

than the pH<sub>f</sub>, the first computation can be made with an acidified feed solution which is 0.5 unit lower than the pH<sub>s</sub> calculated in 7.7.

8.1.3.1 For an assumed pH (pH<sub>acid</sub>), obtained from addition of acid to the feed solution, obtain the ratio of Alk<sub>acid</sub>/C<sub>acid</sub> from Fig. 1. From this ratio, Alk<sub>f</sub>, and C<sub>f</sub> calculate the milligrams per litre of acid used (x). For example, for H<sub>2</sub>SO<sub>4</sub> addition (100 %):

$$\frac{\text{Alk}_{\text{acid}}}{C_{\text{acid}}} = \frac{\text{Alk}_f - 1.02x}{C_f + 0.90x} \quad (8)$$

8.1.3.2 Calculate the total alkalinity of the acidified feedwater (Alk<sub>acid</sub>) and the CO<sub>2</sub> content in the acidified feedwater (C<sub>acid</sub>) as follows:

$$\text{Alk}_{\text{acid}} = \text{Alk}_f - 1.02x \quad (9)$$

$$C_{\text{acid}} = C_f + 0.90x \quad (10)$$

8.1.3.3 Using Alk<sub>acid</sub>, C<sub>acid</sub>, and the supplier's value for SP<sub>alk</sub> for the new pH, calculate the LSI<sub>c</sub> in accordance with Section 7.

8.1.3.4 If HCl (100 %) is used for acidification, the Eq 8 is:



$$\frac{\text{Alk}_{\text{acid}}}{C_{\text{acid}}} = \frac{\text{Alk}_f - 1.37y}{C_f + 1.21y} \quad (11)$$

where:

y = HCl (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  $\text{Alk}_c$ ,  $\text{Ca}_c$ ,  $\text{TDS}_c$ , and  $\text{pH}_c$  of the concentrate stream and compared with the projected  $\text{LSI}_c$  calculated in Section 7.

## 10. Use of Computers for the Determination of $\text{LSI}_c$

10.1 The calculations given in Sections 7 and 8 are adaptable to simple computer analysis.

## 11. Keywords

11.1  $\text{CaCO}_3$  scale; Langelier saturation index; LSI; reverse osmosis; scaling

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