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AMERICAN SOCIETY FOR TESTING AND MATERIALS  
100 Barr Harbor Dr., West Conshohocken, PA 19428  
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## Standard Practice for Calculation and Adjustment of the Stiff and Davis Stability Index for Reverse Osmosis<sup>1</sup>

This standard is issued under the fixed designation D 4582; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice covers the calculation and adjustment of the Stiff and Davis Stability Index (S & DSI) 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 more than 10 000 mg/L of total dissolved solids. For concentrate streams containing less than 10 000 mg/L of total dissolved solids, refer to Practice D 3739.

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 Methods for pH of Water<sup>2</sup>
- D 1888 Test Methods for Particulate and Dissolved Matter in Water<sup>3</sup>
- D 3739 Practice for Calculation and Adjustment of Langelier Saturation Index for Reverse Osmosis<sup>4</sup>
- D 4194 Test Methods for Operating Characteristics of Reverse Osmosis Devices<sup>4</sup>
- D 4195 Guide for Water Analysis for Reverse Osmosis Application<sup>4</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of terms used in the practice, refer to Terminology D 1129.

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

3.2.1 For description of terms relating to reverse osmosis,

refer to Test Methods D 4194.

3.2.2 *Stiff and Davis Stability Index (S & DSI)*<sup>5</sup>—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 Practices

4.1 This practice consists of calculating the S & DSI 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 S & DSI by decreasing the recovery; decreasing the calcium and alkalinity concentrations; 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 differences in salt 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 S & DSI for the concentrate stream from the feed water analyses and the reverse osmosis operating parameters.

5.2 A positive S & DSI indicates the tendency to form a calcium carbonate scale, which can be damaging to reverse osmosis performance. This practice gives procedures for the adjustment of the S & DSI.

### 6. Procedure

6.1 Determine the calcium concentration in the feed solution in accordance with Test Methods D 511 and express as CaCO<sub>3</sub>.

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

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-19 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 1990 *Annual Book of ASTM Standards*, Vol 11.01.

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

<sup>5</sup> Stiff, H. A. and Davis, L. E., "A Method for Predicting the Tendency of Oil Field Waters to Deposit Calcium Carbonate," *Petroleum Transactions*, Vol 195, 1952.

6.3 Determine the total alkalinity of the feed solution using Test Methods D 1067 and express as CaCO<sub>3</sub>.

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

6.5 Measure the temperature of the feed solution.

6.6 Measure the concentration of all major ions using the methods cited in Guide D 4195. At a minimum, measure the concentration of Mg<sup>++</sup>, Na<sup>+</sup>, K<sup>+</sup>, SO<sub>4</sub><sup>-</sup>, and Cl<sup>-</sup>.

**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:

$$Ca_c = Ca_f \times \frac{1 - y(SP_{Ca})}{1 - y}$$

where:

Ca<sub>c</sub> = calcium concentration in concentrate as CaCO<sub>3</sub>, mg/L,

Ca<sub>f</sub> = calcium concentration in feed as CaCO<sub>3</sub>, mg/L,

y = recovery of the reverse osmosis system, expressed as a decimal, and

SP<sub>Ca</sub> = calcium ion passage, expressed as a decimal.

NOTE 1—SP<sub>Ca</sub> can be obtained from the supplier of the specific reverse osmosis system. For most reverse osmosis devices, SP<sub>Ca</sub> can be considered to be zero, in which case the equation simplifies to:

$$Ca_c = Ca_f \times \left( \frac{1}{1 - y} \right)$$

This assumption will introduce only a small error.

7.2 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:

$$Alk_c = Alk_f \times \frac{1 - y(SP_{Alk})}{1 - y}$$

where:

Alk<sub>c</sub> = alkalinity in concentrate as CaCO<sub>3</sub>, mg/L,

Alk<sub>f</sub> = alkalinity in feed as CaCO<sub>3</sub>, mg/L,

y = recovery of the reverse osmosis system, expressed as a decimal, and

SP<sub>Alk</sub> = alkalinity passage, expressed as a decimal.

NOTE 2—SP<sub>Alk</sub> may be dependent on the pH of the feed solution, and its value should be obtained from the supplier of the specific reverse osmosis system.

7.3 Calculate the ionic strength of the feed stream by:

$$I_f = \frac{1}{2} \sum m_i z_i^2$$

where:

I<sub>f</sub> = ionic strength of the feed stream,

m<sub>i</sub> = molal concentration of ion, i (moles/1000 g of water) in the feed solution, and

z<sub>i</sub> = ionic charge of ion, i.

To calculate I<sub>f</sub> use at least all major ions: Ca<sup>++</sup>, Mg<sup>++</sup>, Na<sup>+</sup>, K<sup>+</sup>, HCO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>-</sup>, and Cl<sup>-</sup>.

7.4 Calculate the ion strength of the concentrate stream from the ionic strength of the feed solution, the recovery, and the total dissolved solids of the feed solution by:

$$I_c = I_f \left[ \frac{10^6 - TDS_f}{10^6 - (TDS_f) \left( \frac{1}{1 - y} \right)} \right] \left[ \frac{1}{1 - y} \right]$$

where:

I<sub>c</sub> = ionic strength of the concentrate stream and

TDS<sub>f</sub> = total dissolved solids of the feed solution, mg/L.

7.5 From Fig. 1, obtain pCa as a function of Ca<sub>c</sub> and pAlk as a function of Alk<sub>c</sub>. From Fig. 2 obtain the constant K as a function of concentrate ionic strength and feed temperature.

7.5.1 Calculate the pH at which the concentrate stream is saturated with CaCO<sub>3</sub>(pH<sub>s</sub>) as follows:

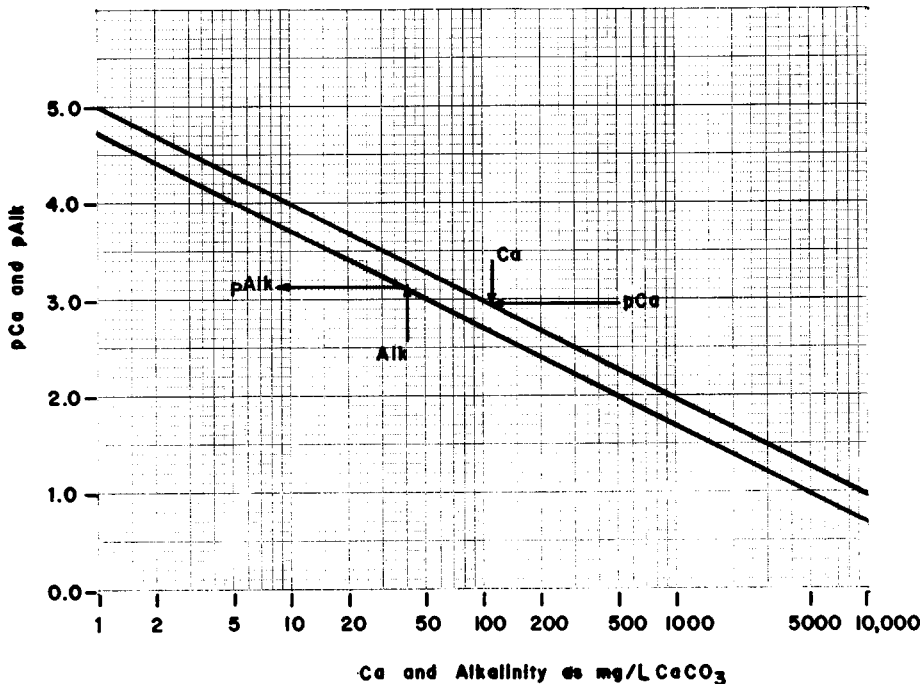


FIG. 1 Conversion of Calcium and Alkalinity to pCa and pAlk