Measuring Scale Forming Potential in Cooling Water

Introduction

Proper cooling water management is essential for preventing corrosion and minimizing scale. While the presence of scale will prevent corrosion, too much scale will impair the operation of the cooling system. Accurate measurement of the parameters which indicate cooling water scaling potential is necessary for attaining the balance between corroding and scaling environments. The Hach® Titralab® AT1000 Titrator and HQD Meter are the best choices for accurate and reliable measurement of these parameters.

Background

Efficient heat transfer is necessary for the proper function of a cooling tower. But heat transfer is significantly hindered by even very thin deposits of scale. Beyond inefficiency, extreme scaling can lead to flow obstruction and eventually equipment failure. Consequently, it is critical to monitor scale forming potential in cooling water.

Scale is the generic term for the deposits which form on the interior surfaces of piping and other equipment which contacts cooling water. Settled solids and precipitated salts can both contribute to scale. The most common scales are salts of alkali earth metals, and the most common of these are calcium salts such as calcium carbonate, $CaCO_3$. Because calcium carbonate is one of the least soluble salts, its saturation point is a useful indicator of the overall scale forming potential of the cooling water.

Precipitation is governed by several water quality parameters: pH, hardness, alkalinity, temperature, and total dissolved solids (TDS). Precipitation will not occur under conditions which favor solubility, where salt concentration is lower than the saturation point. But environments which favor precipitation are common in cooling water circuits. In addition, as cooling water is lost to evaporation and drift, the components of scale are concentrated. This concentration, known as cycling, increases the scaling potential.

Figure 1: Cooling tower pipes

Scale forming potential is frequently approximated by way of an index. Two of the most common indices are the Langelier Saturation Index (LSI) and the Ryznar Stability Index (RSI). These indices use the parameters which control calcium carbonate precipitation to predict whether water tends to be scale-forming, corrosive, or balanced. The LSI is defined as:

$$LSI = pH - pH_s$$

Where pH is the actual pH of the water and pH_s is the saturation pH of $CaCO_3$.

The RSI is based on the LSI, and is defined as:

$$RSI = 2(pH_s) - pH$$

Either index may be calculated once the pH and pH$_s$ are determined.

The solubility of calcium carbonate decreased as pH increases. When the actual pH is greater than the pH at which calcium carbonate is saturated, precipitation and scaling will be favored. This is indicated by a positive LSI, or an RSI < 6. When the actual pH is less than the pH at which calcium carbonate is saturated, solubility, and corrosion will be favored. This is indicated by a negative LSI, or an RSI > 6. An LSI of zero, or RSI of 6, indicates equilibrium. Neither index quantifies the amount of scale present. They only serve as indicators of the potential for scale or corrosion.

While pH is a common parameter and easy to measure with familiar analytical equipment, pH$_s$ is more complicated. pH$_s$ is a relationship between calcium hardness, alkalinity, temperature, and TDS.

pH$_s$ is calculated as:

$$pH_s = 10.0754 + 2.432636e^{\left(\frac{-T}{86.89927}\right)} - 0.2006e^{(-0.004624*TDS)} - \log(Ca\ hardness) - \log(total\ alkalinity)$$

Measuring LSI

Five separate analytical measurements are required to calculate the LSI: pH, calcium hardness, alkalinity, temperature, and total dissolved solids. A number of technologies and instruments exist for measuring each of these parameters individually. But all five parameters can be measured in two easy steps with the Hach Titralab AT1000 Titrator and HQD Meter. The AT1000 will automatically calculate LSI based on the measurement results.

Figure 2: AT1000

Figure 3: HQD and Intellical™

A typical LSI measurement can be accomplished following these steps.

1. Sample conductivity is measured with an HQD meter and Intellical CD401 conductivity probe. Conductivity is used as an estimate of total dissolved solids.
a. Sample handling can be simplified by measuring conductivity in the AT1000 sample beaker. Insert the CD401 probe through the probe port in the AT1000 sample stand head.
2. Launch the Langelier Index Application.
3. Analysis has started. Enter conductivity value when prompted. Measurements of the remaining four parameters are carried out automatically.
4. pH is measured following 15 s of stirring per ISO 10523: 2008.
5. Total alkalinity is measured by titration to pH 4.5 with 0.02 M HCl. Temperature is measured simultaneously.
6. Calcium hardness is measured by titration with Na_2EDTA using an ion selective electrode (ISE).
7. The calculated LSI value is displayed. Values for the measured parameters are also stored and available for reference.

Calculating RSI

The AT1000 does not automatically calculate the RSI. But the RSI may be easily calculated from the LSI measurements.

1. Calculate the pH_s using the measured pH and LSI values.
    $$pH_s = pH - LSI$$
2. Calculate the RSI.
    $$RSI = 2(pH_s) - pH$$

Required Instrumentation

- Titralab AT1000 Potentiometric Titrator, 2 Burettes, 2 Pumps – PN AT1222.97
- pH, Alkalinity & Hardness (ISE) Titration Application Pack – PN AP0005.AT1222
- HQD Meter – PN HQ14D, HQ440D, or HQ430D
- Intellical Conductivity Cell – PN CDC401
- Conical Adapter (optional) – PN LZE122

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