Template-Assisted Crystallization Validated with Scale Saturation Index (SSI)

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Salt-free scale prevention technology of Template-Assisted Crystallization (TAC) addresses the need to reduce maintenance costs, fit within a limited space, and meet higher environmental standards. If you have held off on trying TAC technology due to a lack of reliable and convenient efficacy testing, the Scale Saturation Index (SSI) offers a scientifically sound solution.

What is SSI? It is defined as the difference between the Langelier Saturation Index (LSI) measurements taken at the inlet and outlet of the anti-scale system.

Equation 1:

LSIOutlet – LSIInlet = SSI

A positive LSI implies that the water is supersaturated and calcium carbonate might precipitate and form scale. A negative LSI implies the water is undersaturated and calcium carbonate might dissolve. In practice, there are numerous ways to estimate LSI. In this example, LSI is calculated based upon the following equation:

Equation 2:

LSI = pH + A + B + C + D

Where

A = 0.4341*LN (Alkalinity) + 0.0074
B = 0.4341*LN (Calcium Hardness) - 0.3926
C = –12.1 (When TDS is less than 1000 mg/L)
D = 0.0105*(Temperature, °F) - 0.2368

To calculate SSI of a specific anti-scale system, the following measurements are required at both the outlet and inlet of the system:

pH
Alkalinity (mg/L)
Calcium Hardness (mg/L)
Water temperature (°F)
Total Dissolved Solids (mg/L)

Based on *Eqn.1*, a negative SSI value implies the TAC anti-scale system is effectively changing water characteristics, rendering the treated water less scale forming; a positive SSI implies the system is less effective or ineffective.

Validation

Two types of tests were conducted to validate the SSI method. The first measured actual scale prevention performance in correlation to the calculated SSI value. The second compared the SSI values based on brand new TAC media, used media, and copper fouled media.

Test 1: Correlation of SSI value to scale prevention performance

Tests were based on the German Standard DVGW-W512. It is a 21-day test feeding 14 grains (240 mg/L) hard water through a test chamber that cycles a hot-water heating element on/off constantly throughout the entire day. The treated water volume is calculated based on the net water flowing time and a constant flowrate of 1.0 GPM.

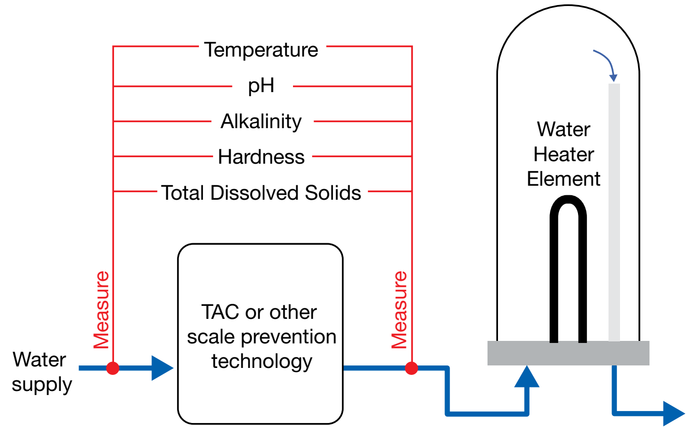

Figure 1. Scale prevention testing schematic

Other scale prevention technologies were also tested side-by-side with TAC technology to compare the scale prevention performance. Water qualities of pH, alkalinity, calcium hardness, temperature and total dissolved solids (TDS) at the treatment inlet and outlet were regularly measured to calculate SSI during the entire testing period.

Test 2: Comparing the SSI value of new TAC media against exhausted and copper fouled media

SSI tests were conducted at three testing sites in the states of FL, TX and AZ simultaneously for comparison purposes. A certified lab analyzed the water quality of the 3 sites. Results are shown in Table 1.

Table 1. Water quality analysis results for AZ, FL and TX test sites

Water Parameter	Units	AZ	FL	TX
Alkalinity	mg/L	120	140	200
Total Hardness	mg/L	200	560	240
pH	NA	7.1	7.2	7.5
TDS	mg/L	580	1300	270
Calcium	mg/L	47.6	102	70.3
Magnesium	mg/L	19.7	73.4	15.3
Silica	mg/L	9.4	20.8	12.1
Chloride	mg/L	200	630	18
Sulfate	mg/L	100	100	17

Test Procedure

- Testing rig utilized TAC cartridges with max flow rate of 1 gpm
- For each test sequence, hard water was circulated through TAC media cartridge for 2.5 hours at varying flow rates. 0.5 gpm for 75 minutes and 1 gpm for 75 minutes
- pH, alkalinity, calcium hardness, temperature and TDS were measured at the inlet of TAC media cartridge before each test run started.
- The same water qualities were measured at the outlet of TAC media cartridge after 15, 75, 90, and 150 minutes of testing.
- LSI and SSI values were calculated for each test run

The above test procedure was repeated:

- Using new TAC media
- Using exhausted media obtained from field installations with approx. 5 year service life.
- Using new TAC media supplied with feed water containing residual copper

Figure 2. SSI Testing setup

Conclusion

Test results have validated SSI for determining the scale prevention effectiveness of TAC media. Negative SSI values correlate to effective scale prevention. Positive SSI values correlate to ineffective scale prevention. In addition, SSI testing is able to differentiate the performance of new, exhausted, or fouled TAC media.

Test Results

Test 1: Correlation of SSI to scale prevention effectiveness

SSI performance of TAC and a second technology ("B") are plotted over the treated water volume in Figure 3. The comparative results indicate that during the time that the initial 250 gallons of water was treated, TAC media was loading up with hardness ions and bicarbonate to form crystals, resulting in the relatively larger SSI (negative) value. After that, the operation became steady state with SSI stabilized and hovered around -0.2 for TAC system. By contrast, SSI values of the technology B stayed positive or around zero for the entire operational process.

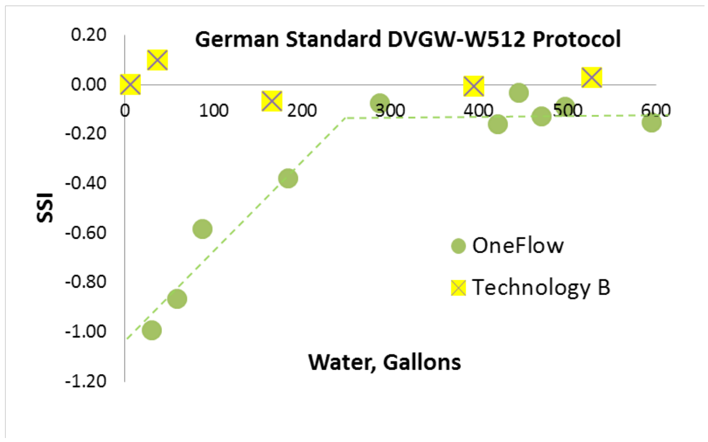

Figure 3. SSI results of TAC vs. Technology B

The corresponding scale prevention results are shown in the photos below (Figure 4). It was noted greater than 95% scale reduction for the TAC system, as shown in the image to the left. By contrast, the second technology ("B") was tested with marginal scale control effect, less than 15% scale reduction, as shown in the image to the right. The results indicate scale reduction activity is well correlated with SSI:

SSI ≥ 0: No significant scale reduction activity
SSI < 0: Significant scale reduction activity

Figure 4. Scale prevention results of TAC vs. Technology B

Test 2: Comparing the SSI value of new TAC media against exhausted and copper fouled media

New TAC Media

The SSI test results based on tests with new TAC media cartridges consistently show negative values across all three testing sites. This finding is exemplified based upon the result obtained in TX (Figure 5).

The recurring SSI pattern among consecutive runs in Figure 5 indicates that virgin TAC media effectively reduces LSI which renders treated water less scale forming. Take the 1st test run in Figure 5 as an example. As the hard water contacts TAC media, calcium and magnesium in the hard water rapidly react with bicarbonate and form crystals on the activation sites of the media surface.

This process consumes hardness ions (calcium and magnesium) and alkalinity (mainly bicarbonate), resulting a decent decrease of SSI (= LSIOutlet – LSIInlet) in the beginning of operation.

As more water is treated by the TAC system, more crystals are formed on the media surface and more activation sites are used up. Therefore the consumption rate of hardness and alkalinity decrease shortly, which partially accounts for the reverse trend of SSI. Another factor for the SSI increase after the initial operation is that some crystals grow large enough to break away from TAC surface. These crystals contribute to the hardness readings in the TAC outlet reading because they are in the microscopic size range.

As the accumulation and release rates of crystals on the TAC media surface reach equilibrium, the scale prevention is stabilized as long as SSI is less than zero. The resting between the consecutive runs refreshes the activation sites of TAC media surface. Therefore, similar SSI patterns are demonstrated in the different testing runs.

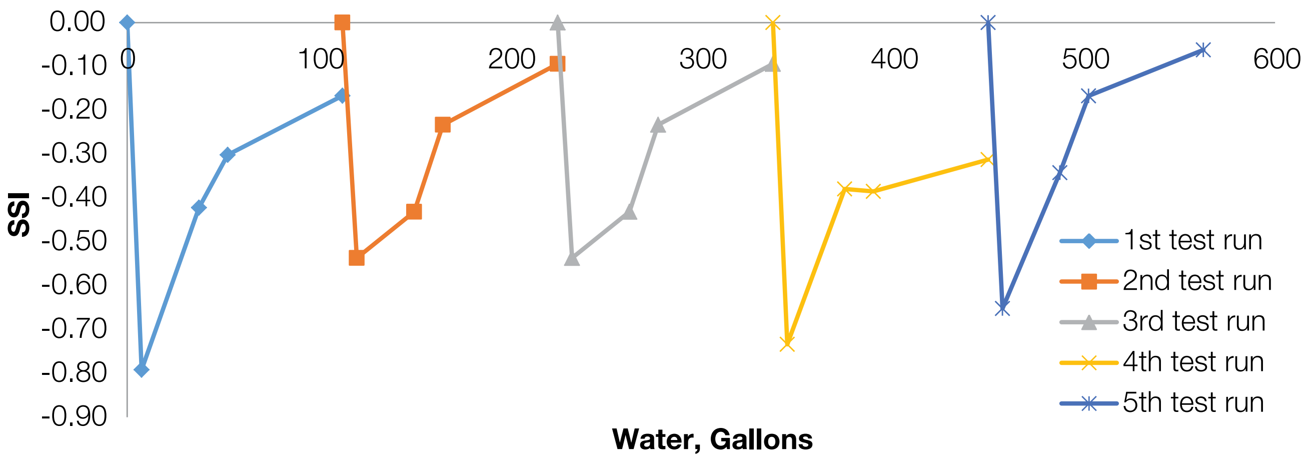

Figure 5. SSI of new TAC media testing in TX

Exhausted TAC Media

As shown in Figure 6, SSI measurements are either slightly positive or hover near zero for the exhausted TAC media having a field service life of approximately five years. It validates that the used TAC media has exhausted scale prevention performance and it is time to replace media.

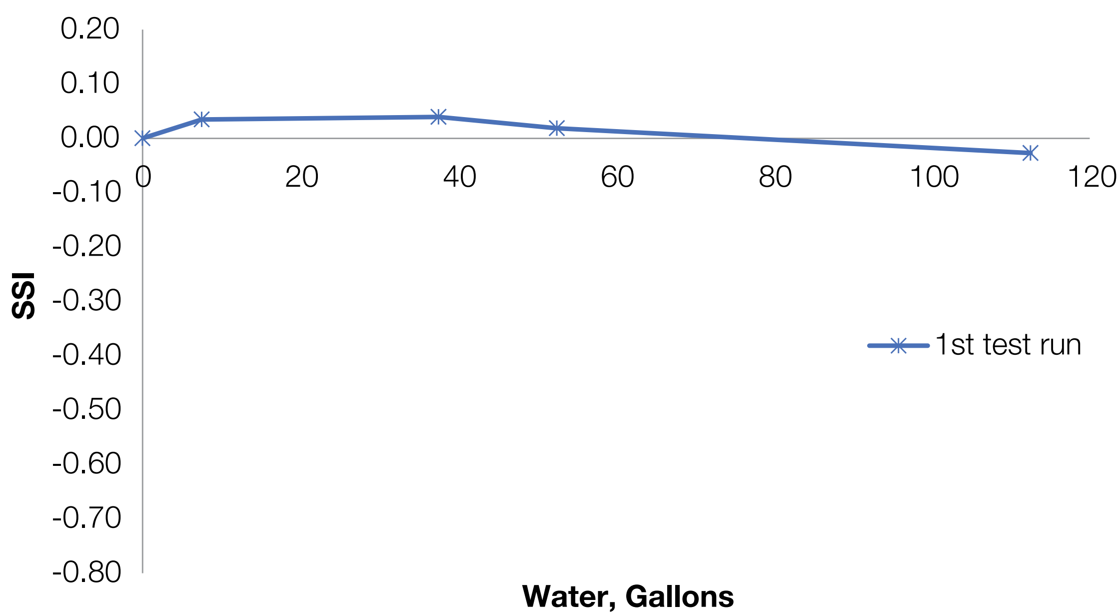

Figure 6. SSI of exhausted TAC media testing

Copper fouled TAC media cartridges

As shown in Figure 7, SSI results in the first two runs demonstrate a consistent pattern as discussed before since TAC media has not been completely fouled by copper yet. However SSI results in the 3rd and 4th runs become positive which implies that TAC media has exhausted scale prevention capacity due to the copper fouling. By comparison, copper has higher affinity to the activation sites of TAC media than calcium or magnesium does. The loaded copper can replace calcium or magnesium and occupy the activation sites of TAC media. Therefore the positive SSI readings are shown in the 3rd and 4th runs in Figure 7.

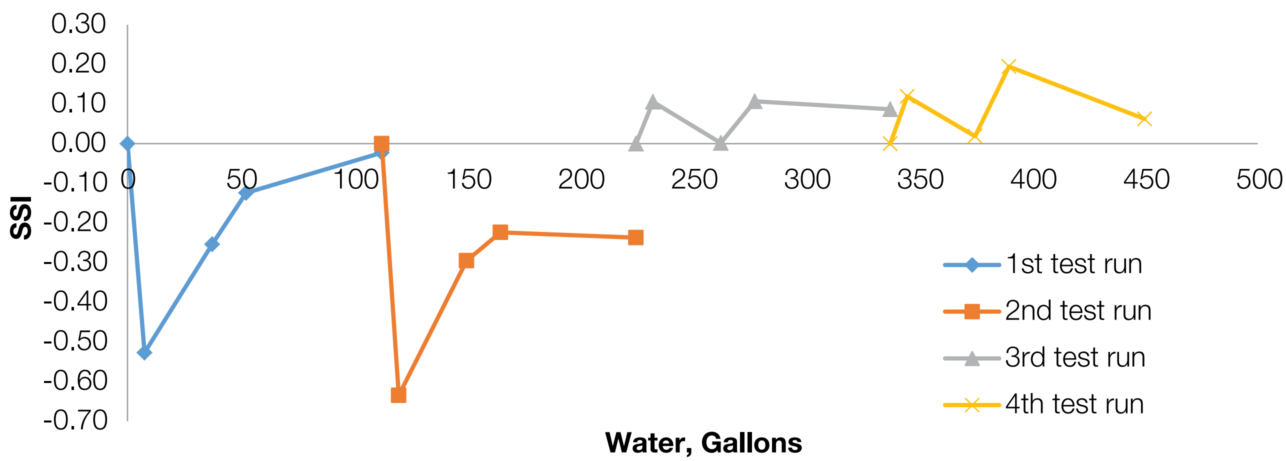

Figure 7. SSI of TAC media testing with feed water of residual copper

When the TAC media is fouled by copper, the media surface characteristics are compromised. Figure 8 compares the new and copper fouled TAC media based on the microscopic view. The glossy surface of copper fouled TAC media indicates the degraded scale prevention effectiveness.

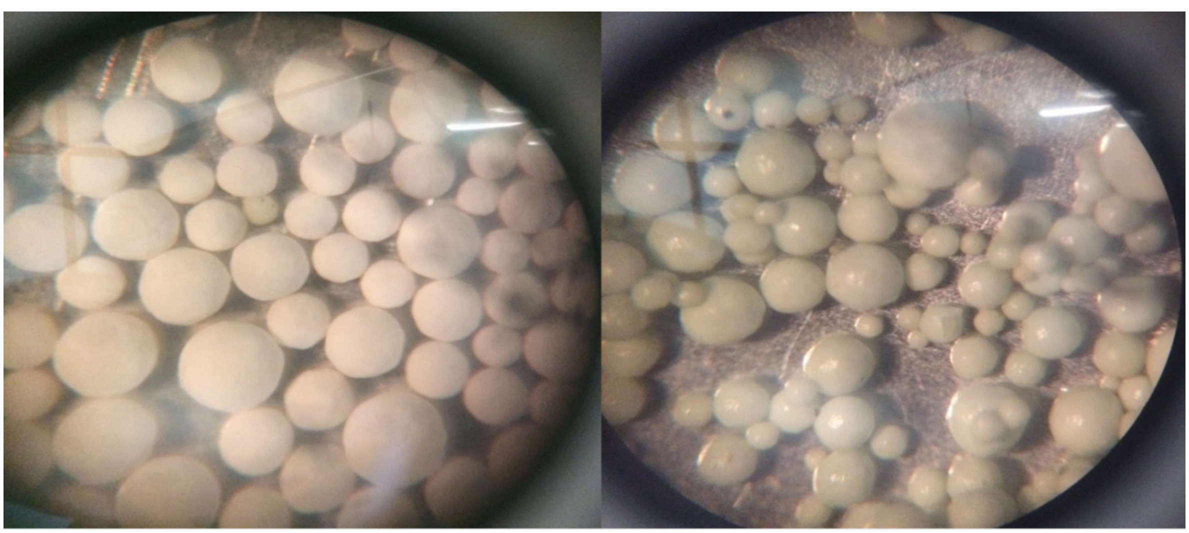

Figure 8. TAC media comparison – new (left) vs. fouled (right)

References

Langelier, W.F. (1936). The analytical control of anti-corrosion water treatment. Journal AWWA, 28 (10).

About Watts

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