

Cooling Systems Calculations

Understanding the Stress..

Before we select the right approach; for both equipment and chemical application; we should determine which driving forces are presence in this cooling systems:

- Scaling?
- Corrosion?
- Bacterial Growth?
- Fouling?



We may easily understand the bacterial risks by visual observation or making dip slide tests, ATP analysis. But the scaling, fouling and corrosion risk evaluations are little bit complicated...



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Cooling Systems Calculation
Scaling
LSI – Langelier Saturation Index



Cooling Systems Calculations

LSI Langelier Saturation Index

The LSI is expressed as the difference between the actual system pH and the saturation pH:

$$LSI = pH \text{ (measured)} - pH_s$$

LSI > 0, water is super saturated and tends to precipitate a scale layer of CaCO_3 .

LSI = 0, water is saturated (in equilibrium) with CaCO_3 . A scale layer of CaCO_3 is neither precipitated nor dissolved.

LSI < 0, water is under saturated and tends to dissolve solid CaCO_3 .

The LSI is most widely used indicator of cooling water scale potential, It is also used to decide qty of water treatment chemicals in the cooling tower or any water system involved in heat transfer. With LSI we can only predict about the nature of water as scaling or corrosion but quantification cannot be derived.



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Cooling Systems Calculations

LSI Langelier Saturation Index

For calculating LSI, it is necessary to know the;

- Alkalinity (mg/l as CaCO_3)
- Calcium hardness (mg/l Ca^{2+} as CaCO_3)
- Total dissolved solids (mg/l TDS)
- Actual pH
- Temperature of the water ($^{\circ}\text{C}$)

$$LSI = pH - pH_s$$

pH is the measured water pH

pH_s is the pH at saturation in calcite or calcium carbonate and is defined as:

$$pH_s = (9.3 + A + B) - (C + D)$$

$$A = (\text{Log}_{10} [\text{TDS}] - 1) / 10$$

$$B = -13.12 \times \text{Log}_{10} (^{\circ}\text{C} + 273) + 34.55$$

$$C = \text{Log}_{10} [\text{Ca}^{2+} \text{ as } \text{CaCO}_3] - 0.4$$

$$D = \text{Log}_{10} [\text{alkalinity as } \text{CaCO}_3]$$



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Cooling Systems Calculations

LSI Langelier Index

The LSI index is calculated at two temperatures: 25°C (room temperature) and 82°C. Lets check the LSI based on mentioned temperatures

Water Analysis:

- $\text{pH} = 7.5$
- $\text{TDS} = 320 \text{ mg/L}$
- Calcium = 150 mg/L (or ppm) as CaCO_3
- Alkalinity = 34 mg/L (or ppm) as CaCO_3

SAMPLE



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LSI Formula:

- $\text{LSI} = \text{pH} - \text{pH}_s$
- $\text{pH}_s = (9.3 + A + B) - (C + D)$

where:

$$A = (\text{Log}_{10}[\text{TDS}] - 1)/10 = 0.15$$

$$B = -13.12 \times \text{Log}_{10}(\text{°C} + 273) + 34.55 = 2.09 \text{ at } 25^\circ\text{C} \text{ and } 1.09 \text{ at } 82^\circ\text{C}$$

$$C = \text{Log}_{10}[\text{Ca}^{2+} \text{ as } \text{CaCO}_3] - 0.4 = 1.78$$

$$D = \text{Log}_{10}[\text{alkalinity as } \text{CaCO}_3] = 1.53$$

Cooling Systems Calculations

LSI Langelier Index

SAMPLE

•Calculation at 25°C:

- $\text{pH}_s = (9.3 + 0.15 + 2.09) - (1.78 + 1.53) = 8.2$
- $\text{LSI} = 7.5 - 8.2 = - 0.7$
- Hence **No Tendency to Scale**

•Calculation at 82°C:

- $\text{pH}_s = (9.3 + 0.15 + 1.09) - (1.78 + 1.53) = 7.2$
- $\text{LSI} = 7.5 - 7.2 = + 0.3$
- Hence **Slight Tendency to Scale**



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Cooling Systems Calculations

LSI Langelier Index

Today we are making this calculation by excel sheets or in online calculating modules. But it very important to understand the roots of the calculations.

As we learned LSI directly depends on following parameters and particuylarly we may control these parameters with different approaches*

- Alkalinity
- Calcium Hardness
- Total Dissolved Solids (TDS),
- Actual pH,
- Temperature of the water (°C).

We need to be sure the LSI values are acceptable for our treatment before we push the start button.



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Cooling Systems Calculations
Scaling/Corrosion
RYZNAR Stability Index



Cooling Systems Calculations

RYZNAR Stability Index

The Ryznar index is a tool that is used to predict the likelihood of calcium carbonate scale to form in a given sample of water. It was created by John Ryznar in the 1940s in an attempt to provide the scientific community with a more accurate predictor of calcium carbonate scaling.

The Ryznar index is also known as the Ryznar Stability Index. RSI takes the form:

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

- pH is the measured water pH
- pH_s is the pH at saturation in calcite or calcium carbonate

The empirical correlation of the Ryznar stability index can be summarized as follows:

RSI << 6 the scale tendency increases as the index decreases

RSI >> 7 the calcium carbonate formation probably does not lead to a protective corrosion inhibitor film

RSI >> 8 mild steel corrosion becomes an increasing problem.



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Cooling Systems Calculations

RYZNAR Stability Index

Ryznar Stability Index Calculation Formula:

RSI Formula
$A = (\text{LOG}_{10} * (\text{TDS}) - 1) / 10$
$B = (-13.12 * \text{LOG}_{10}(\text{temp} + 273)) + 34.55$
$C = \text{LOG}(\text{CaH}) - 0.4$
$D = \text{LOG}_{10}(\text{M-Alk})$
$\text{pHs} = (9.3 + A + B) - (C + D)$
$\text{RSI} = 2\text{pHs} - \text{pHa}$

TDS = Total Dissolved Solids(ppm)

Temp = Temperature(dEG C)

CaH = Calcium Hardness(ppm as CaCO₃)

M-Alk = M-Alkalinity(ppm as CaCO₃)

pHs = Saturation pH

pHa = Actual pH



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Cooling Systems Calculations

RYZNAR Stability Index

SAMPLE



pH	8.0	$A = (\text{LOG}_{10} * (\text{TDS}) - 1) / 10$
Total Dissolved Solids	500 mg/L	$B = (-13.12 * \text{LOG}_{10}(\text{temp} + 273)) + 34.55$
Temperature	30 °C	$C = \text{LOG}(\text{CaH}) - 0.4$
Calcium Hardness	250 ppm as CaCO_3	$D = \text{LOG}_{10}(\text{M-Alk})$
M-Alkalinity	100 ppm as CaCO_3	$\text{pH}_s = (9.3 + A + B) - (C + D)$

Finally,	A	0.17
$\text{RSI} = 2\text{pH}_s - \text{PHa}$	B	2.02
$\text{RSI} = (2 * 7.49) - 8.0 = \mathbf{6.98^*}$	C	2.0
	D	2.0
	pH_s	7.49

* The tendency of this water is slightly scale forming.

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Cooling Systems Calculations
Scaling
Stiff Davis Index



Cooling Systems Calculations

Stiff Davis Index*

The Stiff-Davis index attempts to overcome the shortcomings of the Langelier Index with respect to high total dissolved solids' waters and the impact of "common ion" effects on the driving force for scale formation.

Like the LSI, the Stiff-Davis index has its basis in the concept of saturation level. The solubility product used to predict the pH of saturation (pH_s) for a water is empirically modified in the Stiff-Davis index.

Stiff-Davis indices will predict that a water is less scale forming than the LSI calculated for the same water chemistry and conditions. The deviation between the indices increases with ionic strength. Interpretation of the index is by the same scale as for the Langelier Saturation index.

* Frequently used in high salinity water like sea etc..



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Cooling Systems Calculations

Stiff Davis Index

$$S\&DSI = pH - pCa_T - pAlk_T - K$$

pH is the pH of the water,

pCa is the negative of the logarithm of the total calcium concentration in moles/kg/w,

$pAlk$ is the negative of the logarithm of total alkalinity expressed as moles/kg/w of bicarbonate,

K is a coefficient, the value of which depends on the salinity and temperature of the water.



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Cooling Systems Calculations
Scaling/Corrosion
Larson Skold Index



Cooling Systems Calculations

Larson Skold Index

The Larson-Skold index describes the corrosivity of water towards mild steel.

The index is the ratio of equivalents per million (epm) of sulfate (SO_4^{2-}) and chloride (Cl^-) to the epm of alkalinity in the form bicarbonate plus carbonate:

$$\text{LSkold index} = (\text{epm Cl}^- + \text{epm SO}_4^{2-}) / (\text{epm HCO}_3^- + \text{epm CO}_3^{2-})$$

Index << 0.8 chlorides and sulfate probably will not interfere with natural film formation

0.8 << index << 1.2 chlorides and sulfates may interfere with natural film formation. Higher than desired corrosion rates might be anticipated

Index >> 1.2 the tendency towards high corrosion rates of a local type should be expected as the index increases



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continuously winning solutions

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