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Water Treatment Rules of Thumb

Myths or Useful Tools

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The Philosophers Stone

- Transmute Lead into Gold
- Predict All Problems In A Cooling System
- Recommend Optimum Control Range
- Recommend Treatment and Optimum Dosage

Rules of Thumb

- Used To Predict Scale
- Used To Set Control Limits
- Used To Select Treatment and Ballpark Dosage

TOOLS AND RULES

- Rules of Thumb
- Indices
- Mathematical Models
- Rigorous Theoretical Models

INDICES

- Based Upon Analytical Values
- Simple Corrections for Temperature, TDS
- Ignore Ion Pairs, Bound Ions

Rigorous Models

- Correct Analytical Values
- Rigorous Corrections for Temperature, TDS
- Consider Ion Pairs, Bound Ions

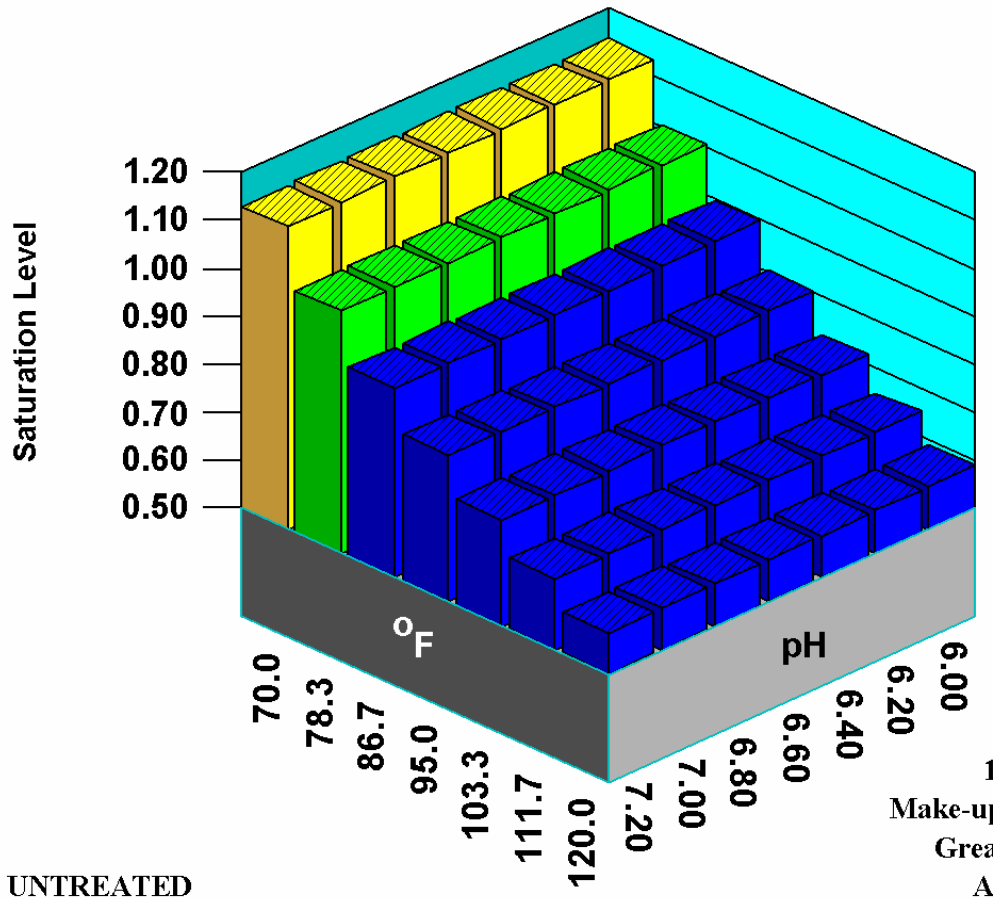
Scales Discussed Today

- Amorphous Silica
- Magnesium silicate
- Calcium sulfate
- Calcium carbonate

Silica Rules of Thumb Comparison

Program	Limit	pH Range	Temperature	Comments
Acid Chromate Acid Phosphate	120 ppm SiO_2	5.8 – 7.2	1.0 x Saturation at 77 ^oF	pH adjustment for $CaCO_3$, $Ca_3(PO_4)_2$ control
Alkaline Zinc Alkaline PO_4	150 ppm SiO_2	7.2 – 7.6	1.0 x Saturation at 85 ^oF	Phosphonates/Polymers for $CaCO_3$, $Ca_3(PO_4)_2$ control
No pH Control	180 ppm SiO_2	8.6 – 9.0+	1.0 x Saturation at 85 ^oF	Phosphonates/Polymers for $CaCO_3$, $Ca_3(PO_4)_2$ control

Silica Saturation Level

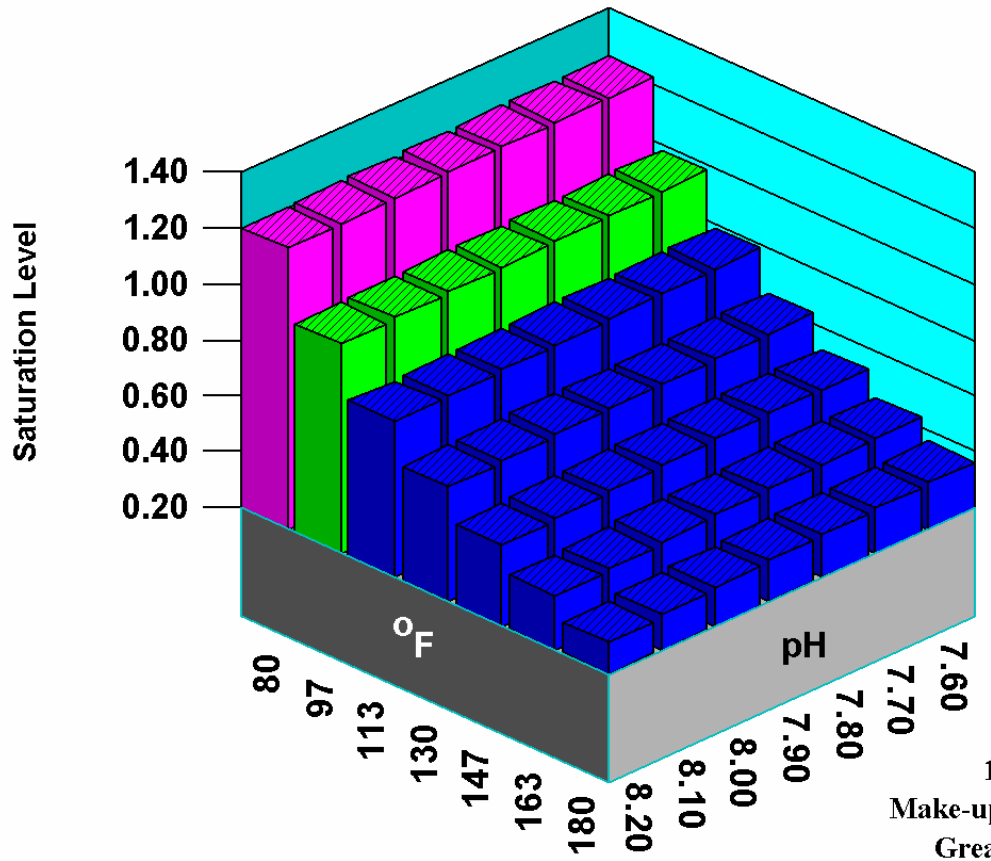


OPERATING RANGE PROFILE
at 4.00 cycles

120 ppm Silica
Make-up SiO2 30 ppm
Great Lakes Water
Acid PO4/CrO4

UNTREATED

Silica Saturation Level

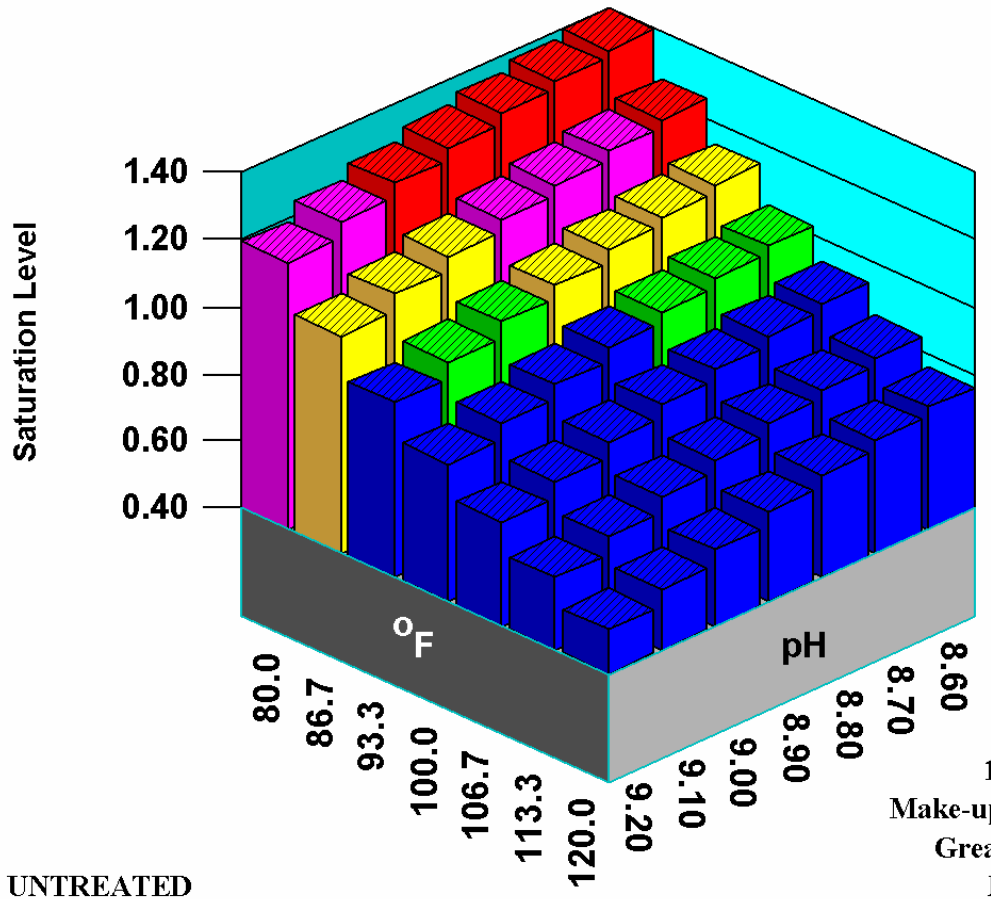


OPERATING RANGE PROFILE
at 5.00 cycles

150 ppm Silica
Make-up SiO2 30 ppm
Great Lakes Water
Alkaline PO4/Zn

UNTREATED

Silica Saturation Level



OPERATING RANGE PROFILE
at 6.00 cycles

180 ppm Silica
Make-up SiO2 30 ppm
Great Lakes Water
No pH Control

UNTREATED

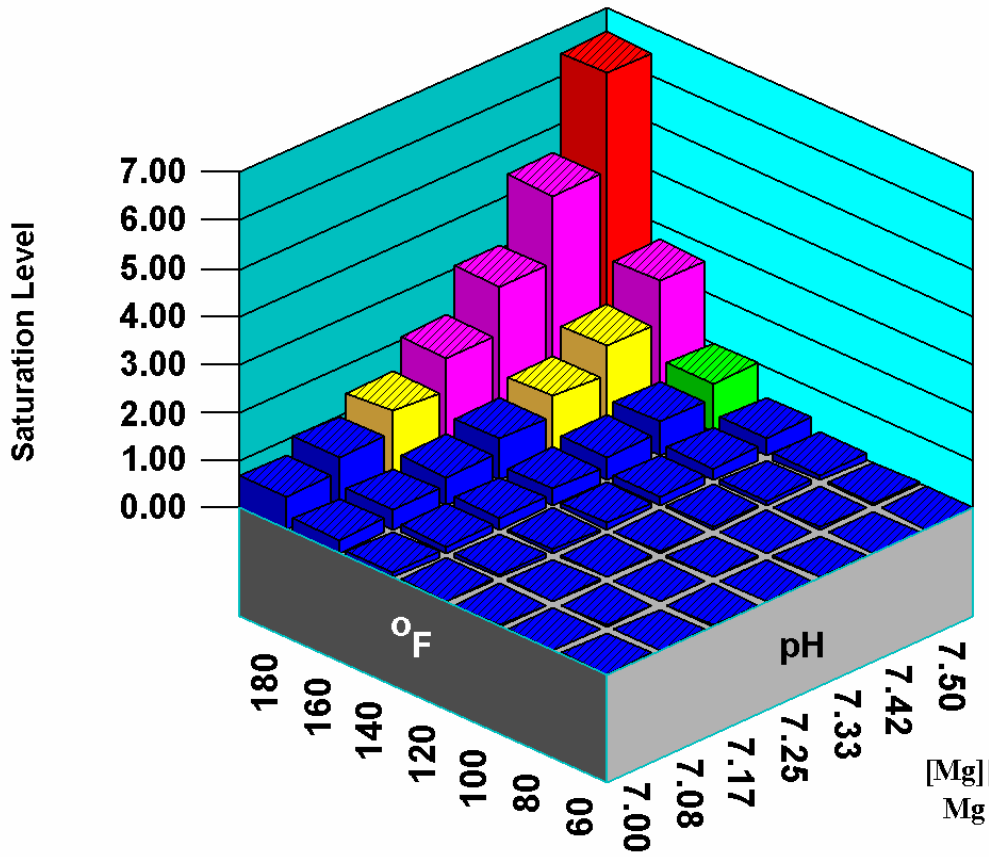
Silica Rules of Thumb Summary

- **Silica Rules of Thumb Correlate well with 1.0 – 1.2 x Saturation at lower temperatures in most systems.**
- **Exercise care when applying to systems where temperatures can be lower than 85°F**
- **Rules of Thumb may be too conservative in hotter systems.**

Magnesium silicate Rules of Thumb Comparison

Program	Limit	pH Range	Temperature	Comments
Acid Chromate Acid Phosphate	120 ppm SiO_2	5.8 – 7.2	1.0 x Saturation at 77 °F	pH adjustment for $CaCO_3$, $Ca_3(PO_4)_2$ control
Alkaline Zinc Alkaline PO_4	150 ppm SiO_2	7.2 – 7.6	1.0 x Saturation at 85 °F	Phosphonates/Polymers for $CaCO_3$, $Ca_3(PO_4)_2$ control
No pH Control	180 ppm SiO_2	8.6 – 9.0+	1.0 x Saturation at 85 °F	Phosphonates/Polymers for $CaCO_3$, $Ca_3(PO_4)_2$ control

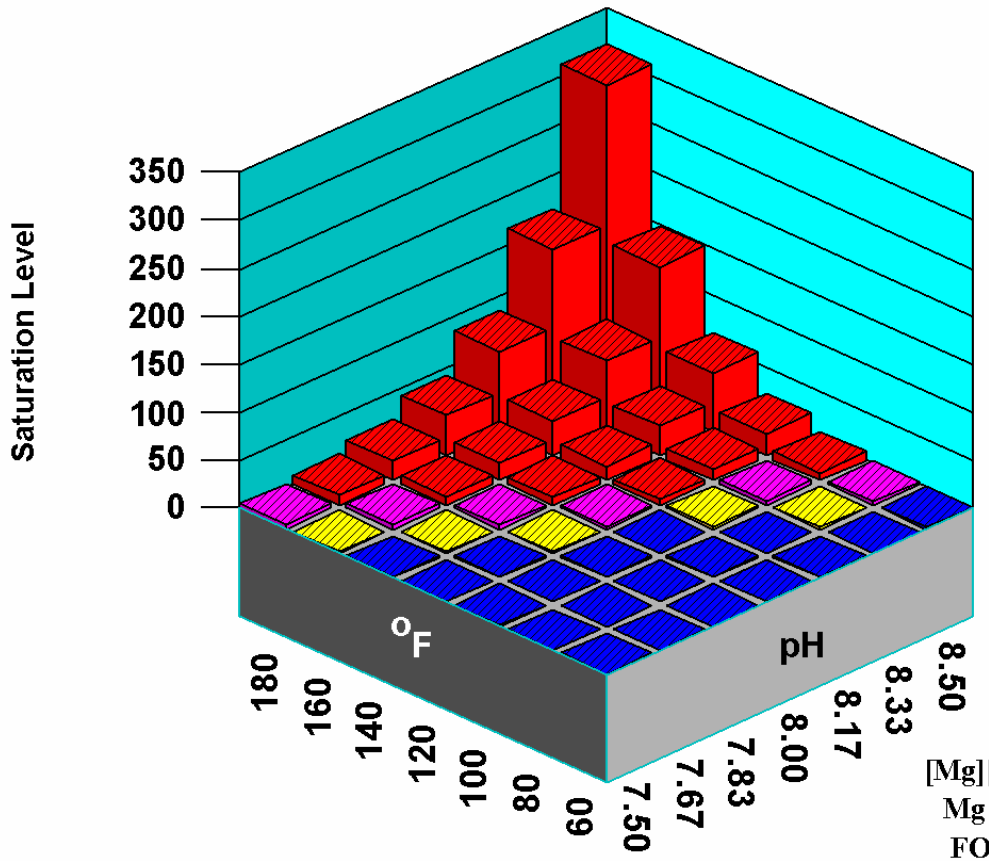
Magnesium Silicate Saturation



[Mg][SiO2] = 17000
Mg 170, SiO2 100
FOR pH < 7.5

UNTREATED

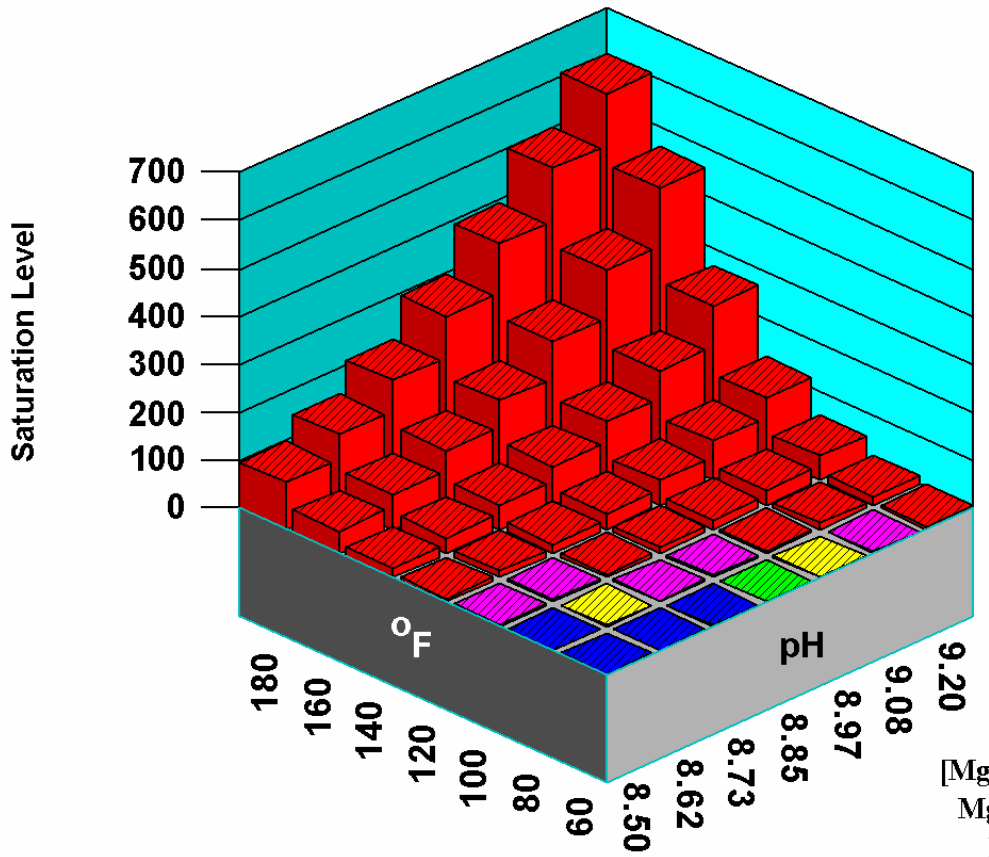
Magnesium Silicate Saturation



[Mg][SiO2] = 12000
Mg 120, SiO2 100
FOR pH 7.5 - 8.5

UNTREATED

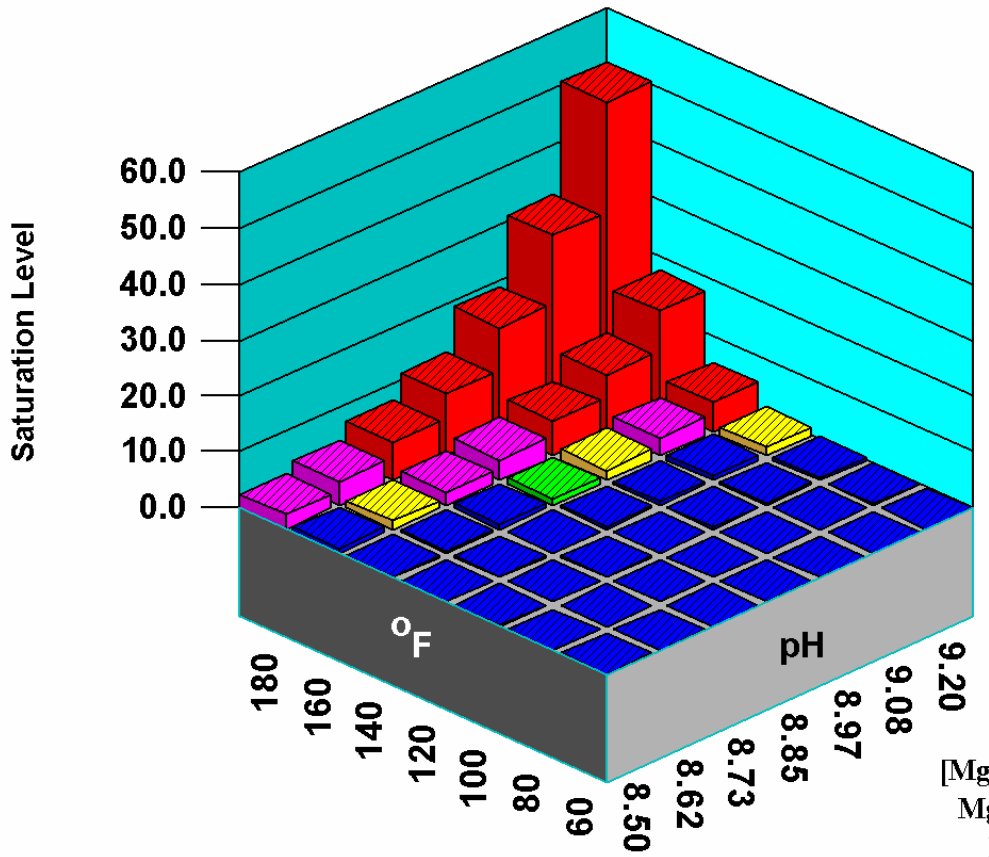
Magnesium Silicate Saturation



[Mg][SiO2] = 6000
Mg 60, SiO2 100
FOR pH > 8.5

UNTREATED

Brucite Saturation Level



[Mg][SiO2] = 6000
Mg 60, SiO2 100
FOR pH > 8.5

UNTREATED

Magnesium Silicate Rules of Thumb Summary

- Mag silicate Rules of Thumb Correlate well in lower end of pH range where potential is low.

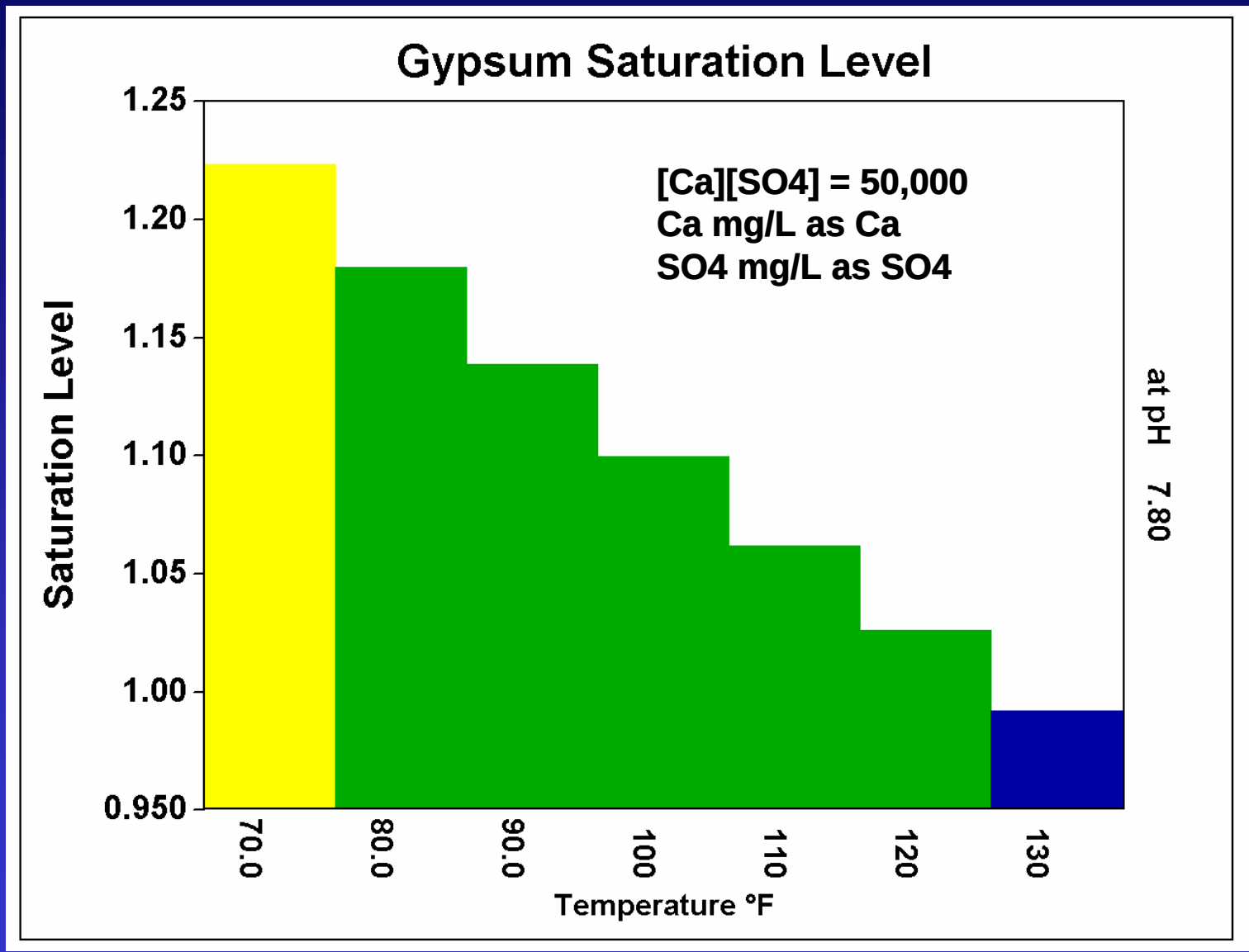
- Exercise care when applying to systems where pH is above 7.8

- Rules of Thumb are confusing to apply.

- Magnesium silicate and Magnesium hydroxide saturation levels greatly preferred.

Calcium sulfate Rules of Thumb Comparison

MINERAL FORM	UNTREATED RULE OF THUMB	SATURATION LEVEL AT LIMIT	TREATED RULE OF THUMB	SATURATION LEVEL AT LIMIT
GYPSUM $CaSO_4*2H_2O$	$[Ca][SO_4] < 50,000$ *Ca as mg/L Ca, SO_4 as mg/L SO_4*	0.96 (at 120 °F)	$[Ca][SO_4] < 10,000,000$ *Ca as mg/L Ca, SO_4 as mg/L SO_4*	4.98 X Saturation (at 120 °F)
ANHYDRITE $CaSO_4$	$[Ca][SO_4] < 50,000$ *Ca as mg/L Ca, SO_4 as mg/L SO_4*	0.99 (at 120 °F)	$[Ca][SO_4] < 10,000,000$ *Ca as mg/L Ca, SO_4 as mg/L SO_4*	3.10 X Saturation (at 120 °F)


Gypsum Saturation Level
[Ca][SO4] = 50,000
Ca mg/L as Ca
SO4 mg/L as SO4
Saturation Level
1.25
1.20
1.15
1.10
1.05
1.00
0.950
70.0
80.0
90.0
100
110
120
130
Temperature °F
at pH 7.80

Calcium sulfate Rules of Thumb Summary

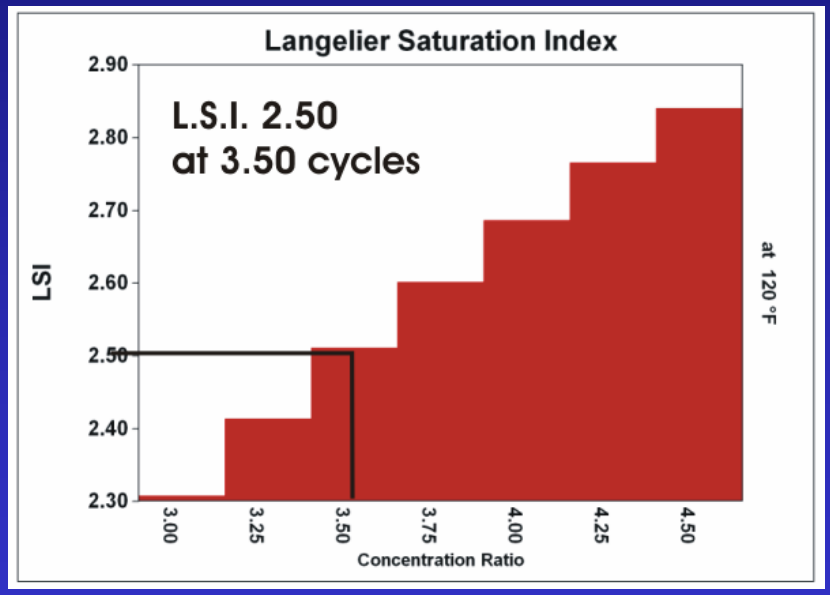
- **Calcium sulfate Rules of Thumb Correlate well with 1.0 – 1.2 x Saturation for Gypsum at 120°F.**
- **Treated Rules of Thumb correlate loosely with 2.5 and 4.0 x Saturation level limits**
- **Saturation levels for Gypsum preferred in lower temperature systems.**
- **Saturation levels for Anhydrite preferred in higher temperature systems.**

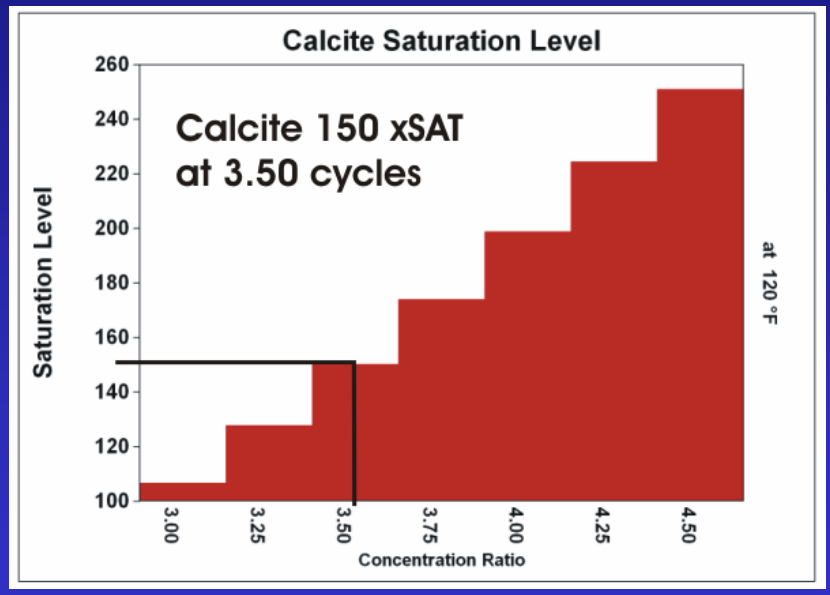
Calcium carbonate Rules of Thumb Comparison

CALCIUM CARBONATE RULES OF THUMB				
Index	**Untreated Limit**	**Treated Limit**	**Stressed Inhibitor Limit**	**Comments**
Langelier Saturation Level	0.0 – 0.2	2.5	3.0	Use alkalinity corrected for noncarbonate (e.g. NH_3, CN, PO_4, Si) alkalinity.
Ryznar Stability Index	6.0 – 5.8	4.0	3.5	Empirical rearrangement of pH and pHs used to calculate Langelier Saturation Index.
Practical Scaling Index	6.0 – 5.8	4.0	3.5	Interpretation similar to Ryznar. Index applicable to NH_3 or other alkali contaminated waters. Calculates a pH as if only carbonic acid based alkalinity present.
Calcite Saturation Level	1.2 – 2.5	135 – 150	200 - 225	Index corrects for ion pairing, noncarbonate alkalinity, activity effects. Reproducible results at the same index.

Treated Limit High Chloride Makeup

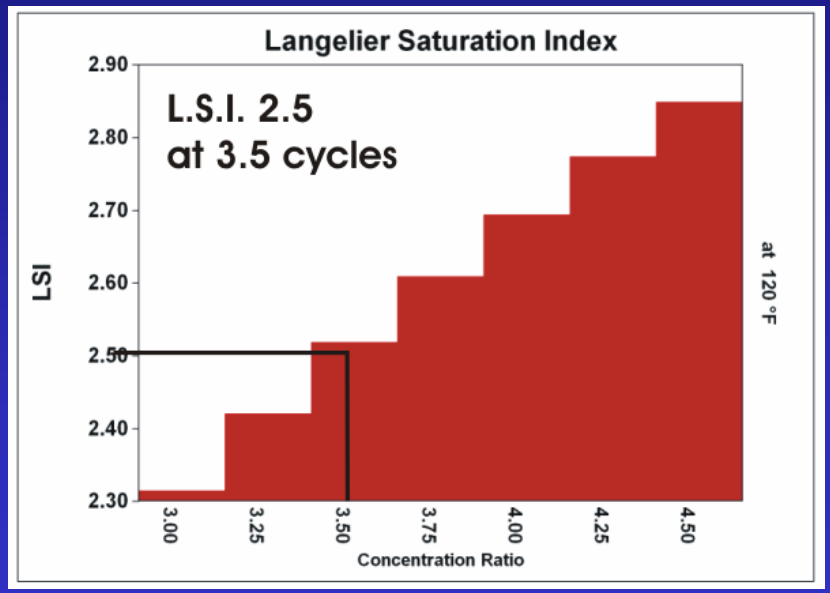
L.S.I. 2.5 Cycles = Calcite 150 xSAT Cycles

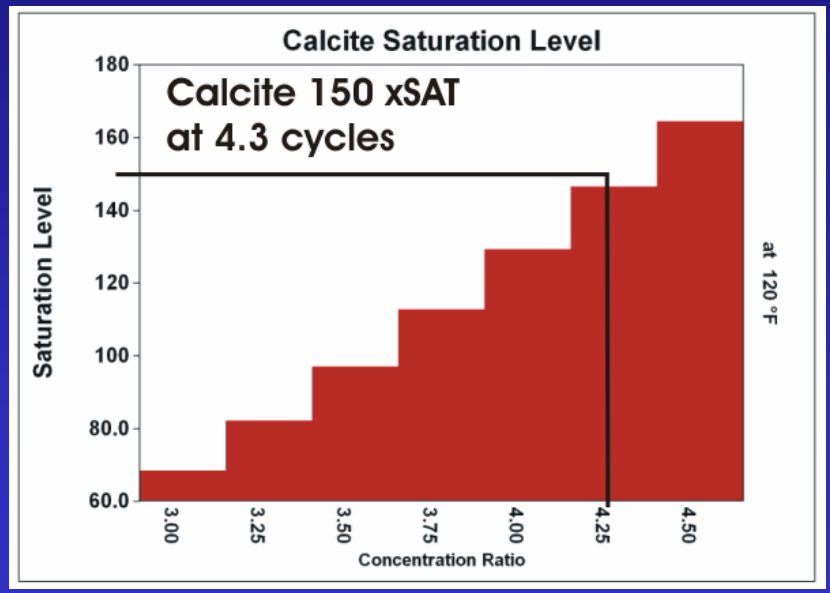




Treated Limit High Sulfate Makeup

L.S.I. 2.5 Cycles << Calcite 150 xSAT Cycles





Calcium carbonate Rules of Thumb Summary

- **Calcium carbonate Rules of Thumb Correlate well with 1.0 – 1.2 x Saturation for calcite.**

- **Treated Rules of Thumb correlate loosely with 150 and 225 x Saturation level limits for common inhibitors.**

- **Saturation levels preferred, especially in higher dissolved solids, high sulfate systems and systems with non-carbonate alkalinity sources.**

Water Treatment Rules of Thumb Summary

- **Rules of Thumb, in general, were derived from simplified saturation level calculations.**
- **Rules of Thumb provide quick-and-dirty guidelines for troubleshooting, evaluating a system.**
- **Ion Association model saturation levels are the preferred method for evaluating scale potential, establishing control limits.**
- **Be leery of Rules of Thumb at extremes of pH, temperature, dissolved solids.**