

COOLING WATER CHEMISTRY 101

Opportunities For Water Savings,
Energy Savings, Maintenance Savings

Leon Shapiro

***VRTX* Technologies**

Arizona **RETA** Chapter

June 26, 2007

Water Chemistry

- Chemistry of Water in a Cooling System is Relatively Simple
- What is in the Water
 - Calcium, Magnesium, Silica
 - Carbonates, Chlorides
 - Bacteria

Water Chemistry

- In an Ideal World, Once Through Cooling Water or Zero Blowdown
- Cooling Water Represents ~60% of the Total Water Consumed in the U.S.
- Just Don't Have Enough Water to do Once Through
- Impurities in the Water Prevent Practical Zero Blowdown
- Reuse the Water as Much as Possible

Cycles of Concentration Defined

- Problems Begin with Evaporation
- Salts in Water Concentrate
- Number of Times Water is Used is Analogous to Cycles of Concentration
- Cycles of Concentration is Defined as:
 - The concentration of a non-evaporative species in the recirculating water divided by the concentration of the same species in the make-up water

Water Chemistry

- Hot Heat Transfer Surfaces Provide Nucleation Sites for Salts to Precipitate as Scale
- Calcium Carbonate Inversely Soluble with Temperature
- Calcium Carbonate Precipitates Onto Hot Surfaces As Calcite



And the Hits Just Keep on Comin'

- Nice Warm Water Provides Ideal Incubator for Bacteria
 - Legionella
 - Pseudimonas aeruginosa
 - Both are extremely harmful
- Biocides Are Corrosive to Metal Surfaces
- Water Itself is Corrosive
- Biofilms also Initiate Corrosion Sites

Cooling Water Problems

Scale

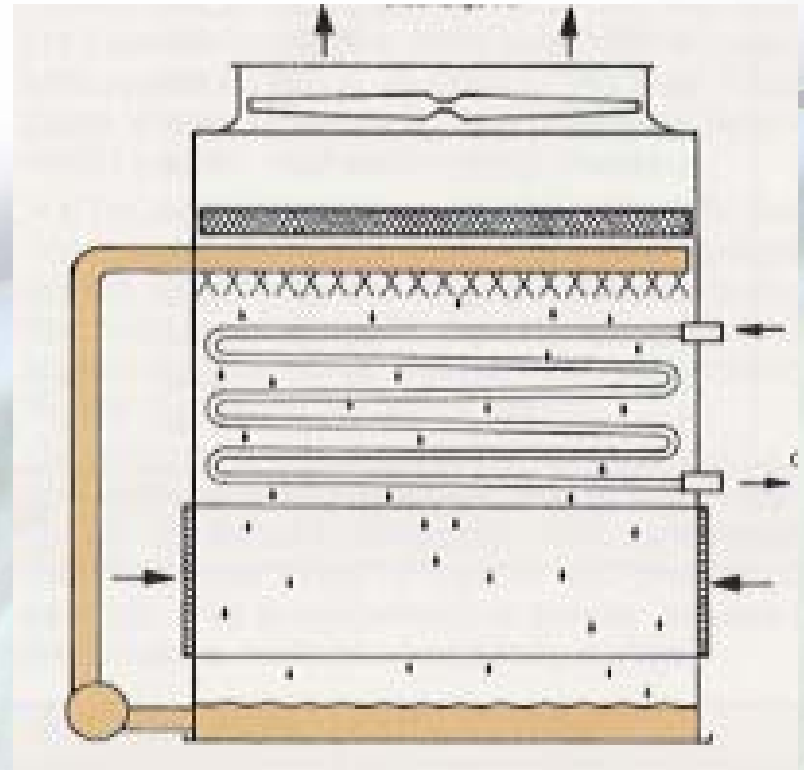
Corrosion

Bacteria

Cooling Water Problems

Evaporative Condensers

Especially Vulnerable
Due to High Evaporation
Rate and Low system
Volume



Solutions?

Call Your Local Chemical Treatment Company

They will Add:

Dispersants for Scale Control

Biocides for Control of Microbiological Growth

Corrosion Inhibitors to Control Corrosion

Solutions?



So What's the
Problem?

Chemical Treatment Solutions Are Part of the Problem

- Dispersants for Control of Calcium
 - Trying to Cheat the Solubility Limits of Calcium Carbonate
 - Limits the Cycles of Concentrations
 - Water Conservation Opportunities are Limited
- Biocides
 - Bacteria Quickly Adapt
 - Different Biocides Must Be Added
 - Extremely Hazardous
 - Becoming More Difficult to Blowdown
- Corrosion Inhibitors
 - Difficult to Maintain Balance Between Inhibition and Corrosivity

Chemical Treatment Solutions Are Part of the Problem



- Chemical Treatment is Like Juggling, Can't Keep All the Balls Up All the Time
- Many Competing Reactions Between Biocides/Corrosion/Scale
- i.e., Most Biocides are Corrosive
- Additives Affect Heat Transfer

Solutions?

- Water/Sewer Costs Increasing
 - Phoenix Area Water Costs Expected to Drastically Increase In Near Future
- Water Availability
 - Many Areas Approaching Current Allotments and Permitted Amounts
- Chemical Costs
 - Chemicals Petrochemical Based, Prices Up ~15%/year Last Three Years
- Regulations
 - Biocides Are Getting More Difficult to Manufacture
 - Regulations Increasing Limiting Blowdown

Options

Non-chemical Treatment

Non-Chemical Treatment

- “Just Weld That Blowdown Shut”
- “Never Needs Monitoring”
- “Just Plug it In”
- “100% Effective Against All Bacteria”



Potential Benefits of Non-Chemical Treatment Technologies

- Eliminates Hazardous Chemicals
- Smaller Water Volume in Evaporative Condensers Actually Favor Non-Chemical Treatment
- Reduce Water Usage by Increasing Cycles of Concentration
- Better Heat Transfer
- Blowdown Can Be Used For Irrigation

Non-Chemical Treatment Technologies

- Magnets
- Electromagnets
- Ozone
- Ultrasound
- Ionization Devices
- Electronic/AC Induced Fields (Pulsed Power)
- Hydrodynamic Cavitation

Non-Chemical Treatment Technologies

- Magnets/Electromagnets
 - Only Claimed Scale Control
 - Sometimes Sold with Copper/Silver Electrodes for Microbial
 - Very Limited Use

Non-Chemical Treatment Technologies

- Ozone Injection
 - Good Idea in Theory
 - Ozone is VERY REACTIVE
 - Difficult to Control
 - Very Corrosive

Also Known as the Disappearing Cooling Tower Technology



Non-Chemical Treatment Technologies

- Ultrasound Treatment
 - Attempts to Alternate Compressing/Decompressing Water to Control Biological Growth
 - Does Not Control Scale

Non-Chemical Treatment Technologies

- Electronic/AC Induced Fields (Pulsed Power)

- Dolphin, Evapco Pulse Pure

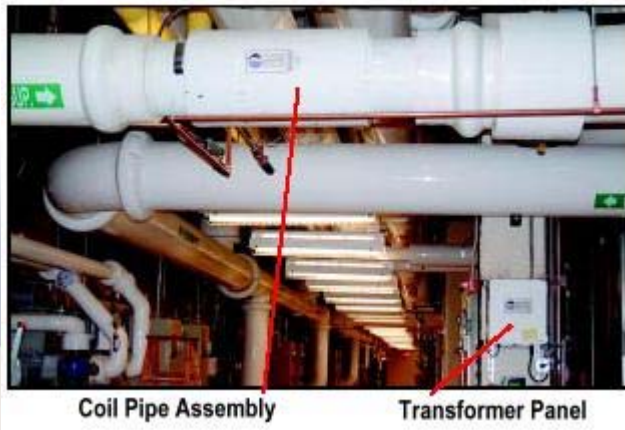
- Promotes Formation of Seed Crystals in Attempt to Favor Solution Precipitation over Surface Deposition

- Stuns Bacteria To Prevent Reproduction

- Systems Are Being Successfully Applied on Small Systems, <200 Tons and in Areas with Very Clean Make-Up Water

- Technology Not Capable of Increasing Cycles of Concentration

Dolphin System Major Components



Coil Pipe Assembly

Transformer Panel

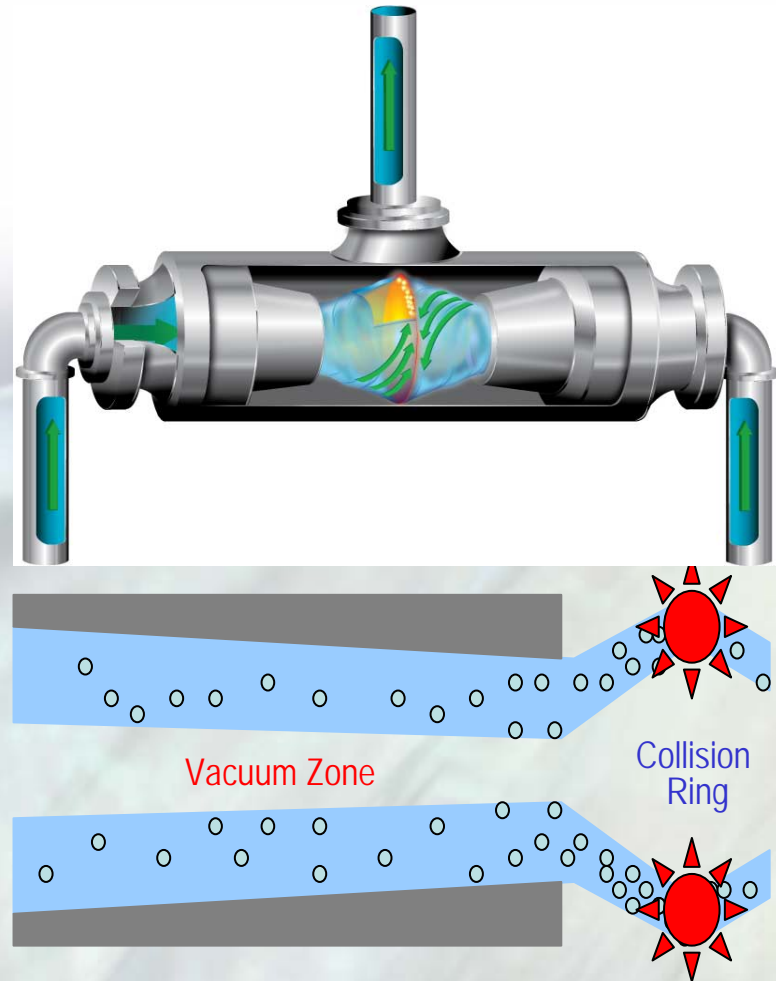
Non-Chemical Treatment Technologies

- **Hydrodynamic Cavitation**
 - Uses Water Pressure to Form CaCO_3 Crystals (Aragonite)
 - Uses Rapid Decompression to Kill Bacteria

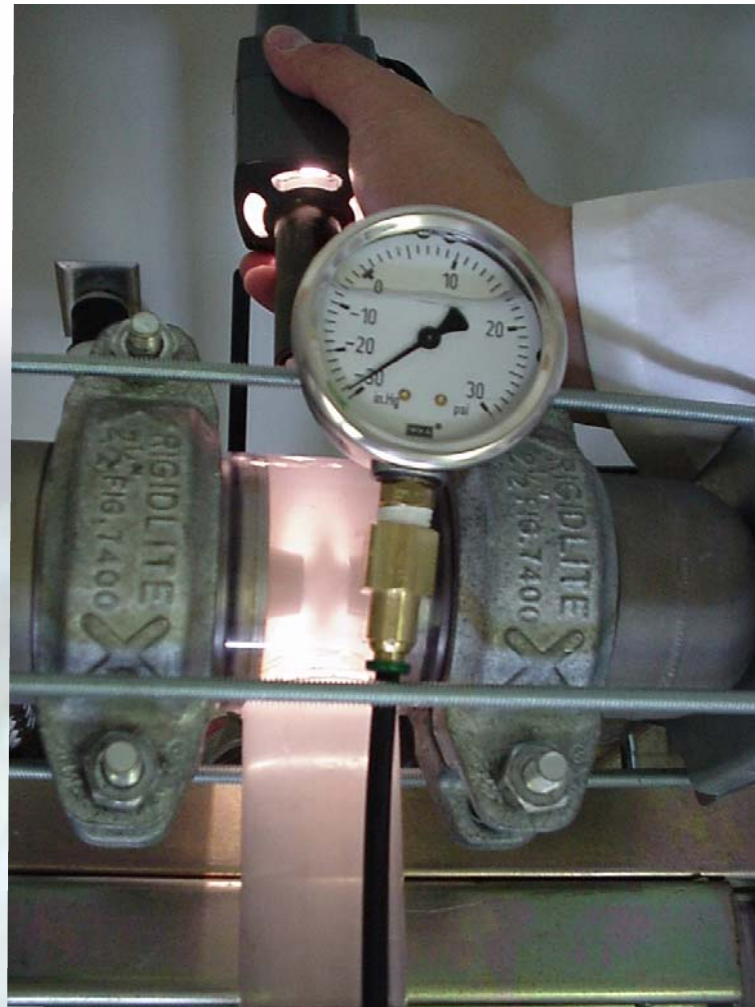
Hydrodynamic Cavitation

- Water is pumped into pressure equalizing chamber, then the water is channeled into the cavitation chamber where it is forced to rotate at high velocity

- ✓ Rotating water streams create strong vacuum
- ✓ Two opposing streams collide at the mid-point of the chamber
- ✓ Micro bubbles form and grow in the vacuum zone
- ✓ The bubbles collapse catastrophically when streams collide



Hydrodynamic Cavitation



Hydrodynamic Cavitation



- Strong vacuum strips CO_2 gas from water and shifts chemical equilibrium to the right
- Hydrodynamic cavitation creates extremely high temperature zone; and the solubility of CaCO_3 is decreased
- Dissolved calcium and carbonate ions are dehydrated and combine to form CaCO_3
- System Also Strips Out Other Dissolved (Corrosive) Gases
- Reaction Naturally Buffers Water at ~8.5-9.2 pH

Hydrodynamic Cavitation

- Cavitation Causes CaCO_3 to Form as **Aragonite** (soft, porous) Versus **Calcite**



Aragonite Crystals



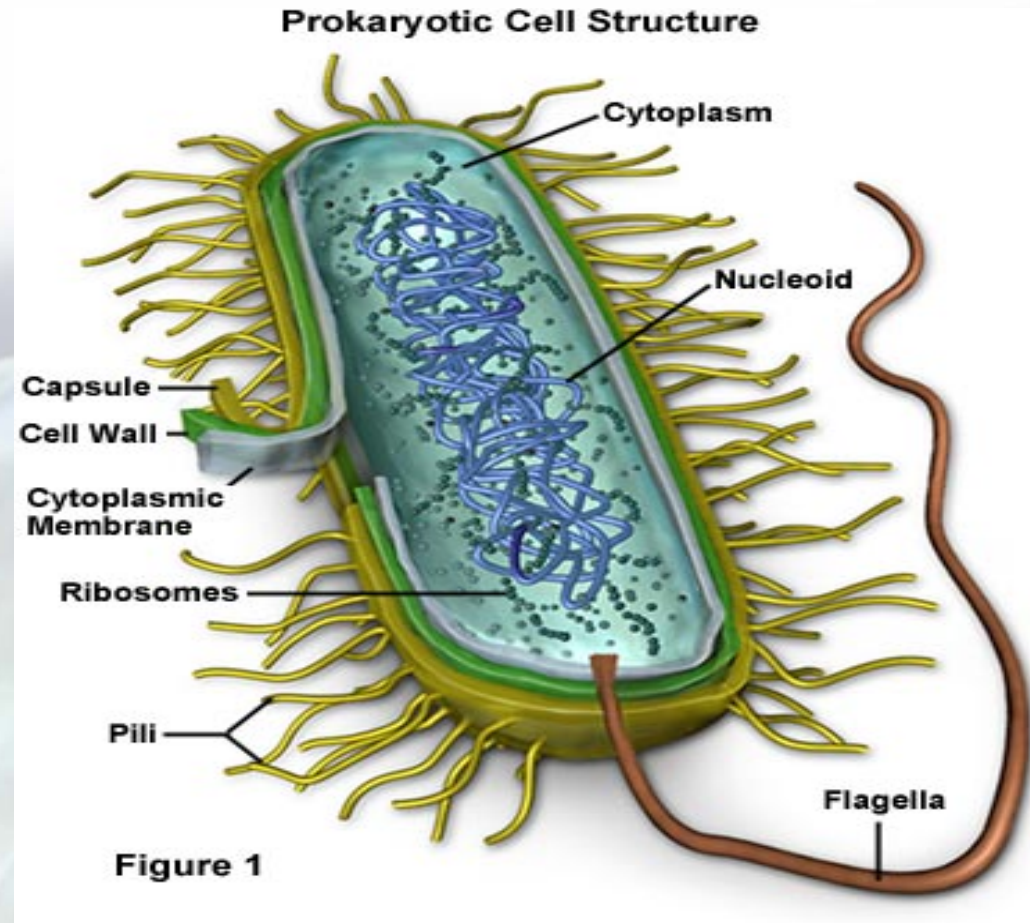
Calcite Crystals

Hydrodynamic Cavitation

- Precipitating CaCO_3 Allows for Easy Removal From Cooling Water System by Centrifugal Separator
- Provides Cleaner Water
- Allows for Increase of Cycles of Concentration

Hydrodynamic Cavitation

- Vacuum Physically Ruptures Cell Walls of Bacteria



Hydrodynamic Cavitation



Hydrodynamic Cavitation



Hydrodynamic Cavitation

- No Chemicals Used
- Saves Water
- Cleaner Water Provides Better Heat Transfer
- Less Maintenance Required to Remove Scale and Clean Sumps
- Blowdown Water Can Be Used For Irrigation

Summary

- Chemical Treatment Works, But is Not an Exact Science
- Regulatory Pressures on Chemical Usage and Water Conservation Will Drive Operators to Non-Chemical Technologies
- Be Afraid, Be Very Afraid of the Black-Box Technologies

Summary

- Two Non-Chemical Technologies Are Well Proven
- Pulse Power for Small (<200 Tons) Towers/Condensers and Areas With Clean Make-up Water
- Hydrodynamic Cavitation for Larger Systems and Provides Water Savings Opportunities
- All Water Treatment Technologies Require Some Ongoing Monitoring

QUESTIONS?

ANSWERS!

SOLUTIONS!