

Chemical Treatment of water for Cooling and Heating Systems

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Georgia Institute
of **Tech**nology

Outline

- Water
- Mechanical systems requiring water treatment
- Water reaction to mechanical systems
- Tools of defense
- Water treatment elements
- Benefit of chemical water treatment
- Alternatives

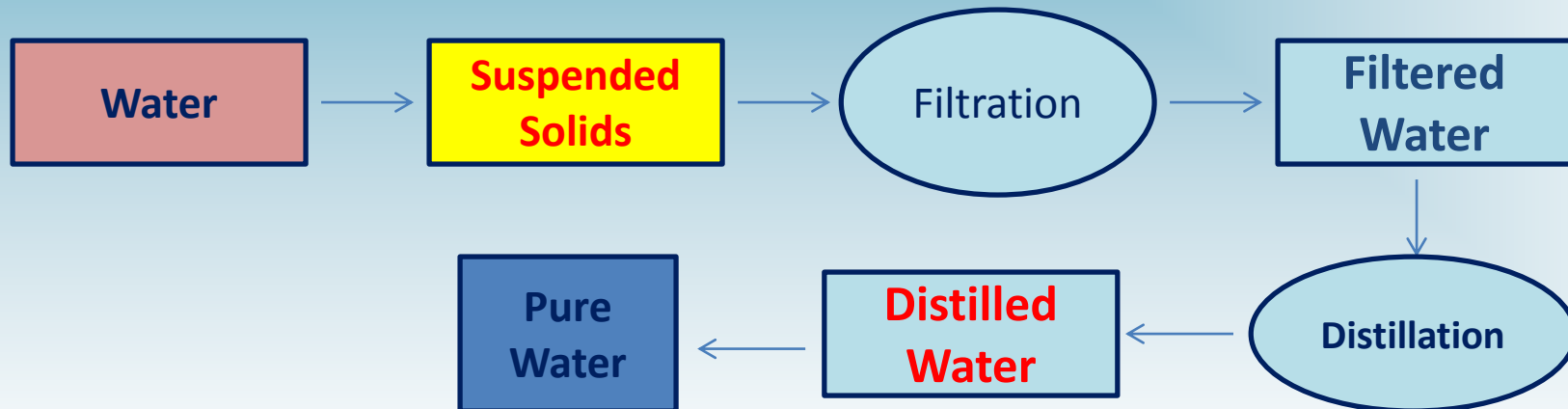
What is Water?

- Water is H₂O
- Water is a “Universal Solvent”
- Water impurities contain dissolved and suspended solids:
 - Hardness
 - Alkalinity
- Metals (iron, copper, aluminum, zinc)
 - Carbon Dioxide
 - Sodium
 - Chlorides



What is Pure Water?

- Pure water is H_2O
 - How do we get pure water
 - Take out the ingredients
 - Suspended solids
 - Dissolved solids
 - Gases
 - Microbiological life
 - ASHRAE 188-This standard provides minimum legionellosis risk management requirements for the design, construction, commissioning, operation, maintenance, repair, replacement, and expansion of new and existing buildings and their associated (potable and non-potable) water systems and components.

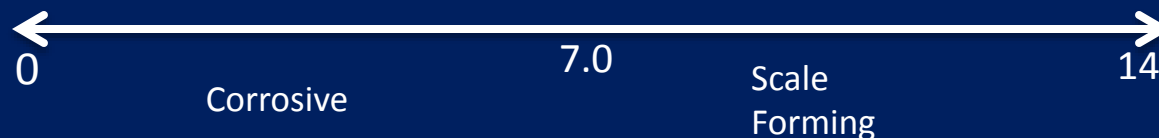
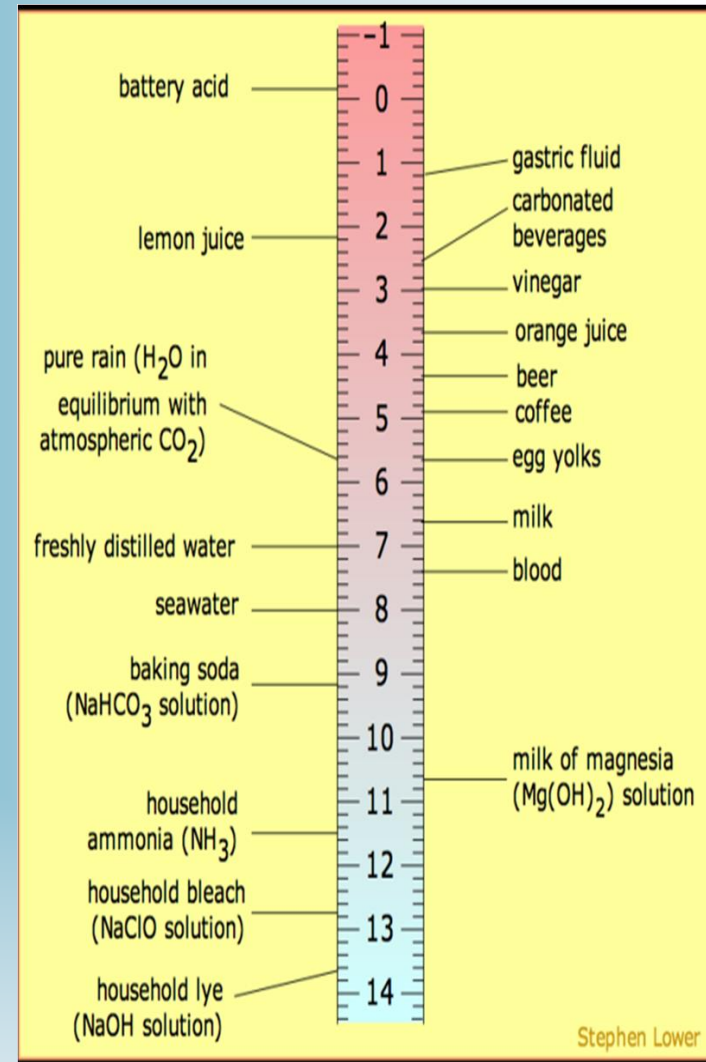


Why the need for Pure Water

- High levels of impurities can pose a major threat to industrial development.
- Removing impurities is necessary to protect and improve operation
 - Possible methods to remove these impurities:
 - Turbidity: Coagulation, filtration
 - Hardness: Softening
 - Alkalinity: Dealkalization
 - Chlorides: Demineralization
 - Iron: Filtration

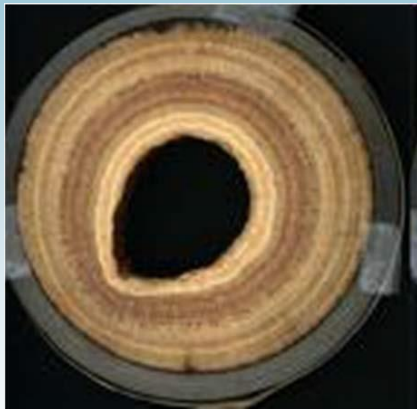
An example of how water properties vary

- Higher with
 - High PH (Alkalinity)
 - Inhibits bacteria
 - Corrosive to Copper
 - Corrosive to Galvanized metal
- Low with
 - Low PH (Acidity)
 - Corrosive to Steel
 - Corrosive to Copper
 - Corrosive to Galvanized metal



Another example of how water properties vary

- Conductivity and Hardness
 - Hardness in water is presence of ionized minerals such as Mg^{++} , Ca^{++}
 - Hardness in water can cause water to form scales
 - Conductivity allows us to quantify hardness
 - Calcium forms hard calcium carbonate scale and Magnesium forms magnesium silicate in boiler



Calcium Carbonate Scale



Magnesium Silicate Scale

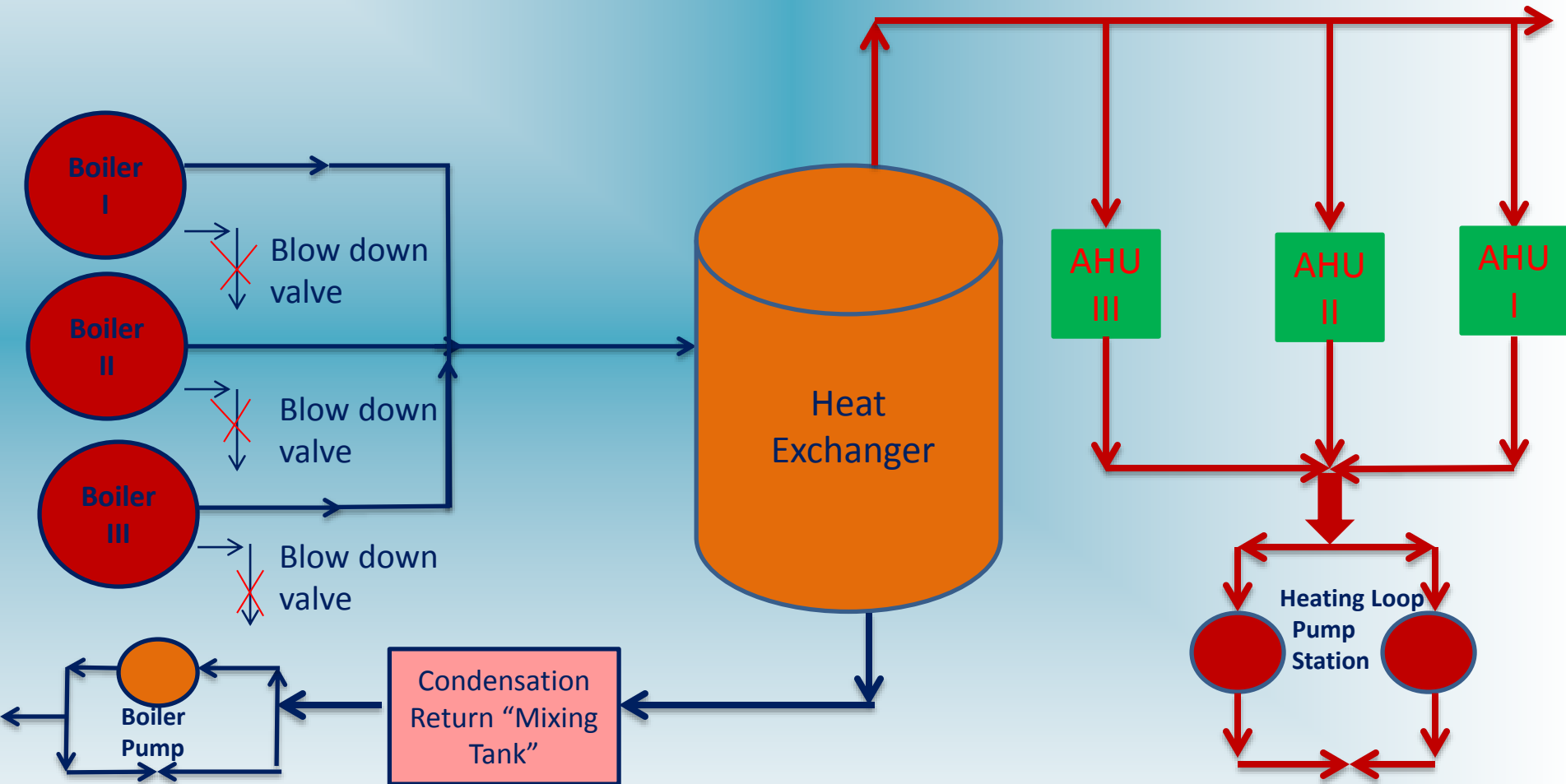


Mechanical Systems

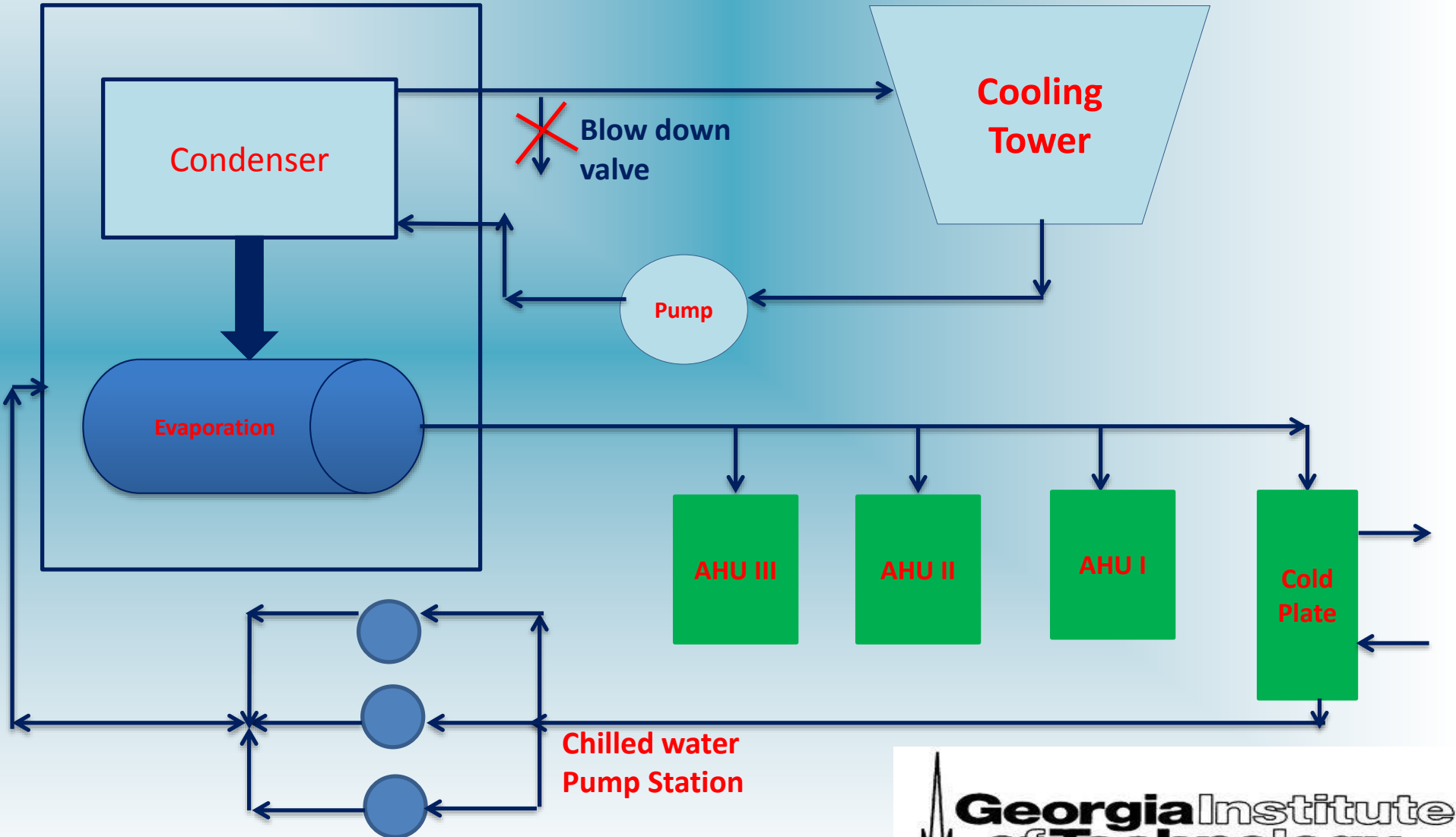
- Heating Loop
 - Boiler tubes, pipes, heat exchangers
 - Boiler internals, barrels, girder
 - Steam & Condensate distribution system
- Cooling Loop
 - Tower Basin
 - Tower Internal filling
 - Tower distribution system
 - Pumps
 - Chiller tubes, pipes and heat exchangers condensers
 - Chilled water distribution system



Heating Loop



Cooling Loop



Water's reaction to Mechanical systems

- Impact of Water Chemistry
 - Scaling
 - Corrosion
 - White Rust
 - Fouling
 - Microbial growth



Scaling

- **Scaling** is the formation of a thin, plate like piece, lamina, or flake that peels off from a surface of mechanical system in contact with water, as from the skin.
- Scaling increases with increasing Temperature
- Scaling increases with increasing pH
- Other factors which affect scaling are:
 - Alkalinity
 - Conductivity
 - Proportion of suspended solids
 - Velocity of water

- **Effects of Scaling**

- Reduces Heat transfer efficiencies
- Decrease efficiencies
- Increase Tube failures
- Increase operational c



Corrosion

- **Corrosion** is the destruction of metal or alloy gradually by a chemical reaction, especially by oxidation.
 - Corrosivity of dissolving oxygen in water doubles for every 18 F increase in temperature
 - Corrosivity of water increases as pH increases—Corrosion layer is compromised at low and high pH at higher temperatures. A pH between 7 and 10 gives a lower rate of corrosion.
 - Corrosivity of water increases as conductivity increases

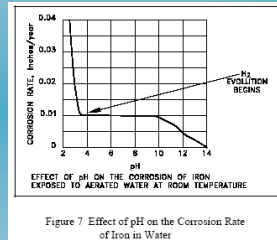
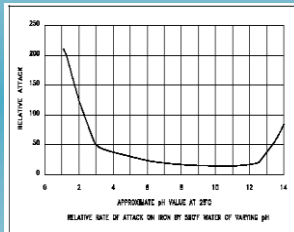
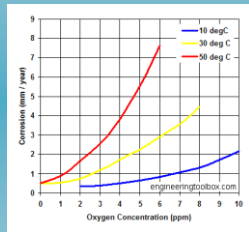
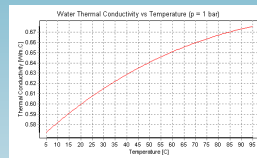
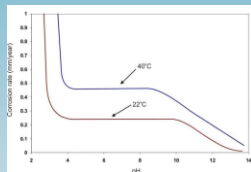
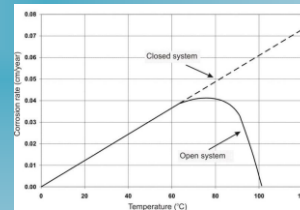


Figure 7 Effect of pH on the Corrosion Rate of Iron in Water



Typical erosion/corrosion



Corrosion damage seen on pipe

- **Effects of Corrosion**
 - Destroys system metal
 - Reduced heat transfer efficiency
 - Produces leaks in equipment
 - Contaminates process fluid
 - Increase operational cost



White Rust

- **White Rust** is an accumulation of an appreciable volume of a soft, white, fluffy, non-protective zinc corrosion product on galvanized surfaces.



Galvanized sheet metal

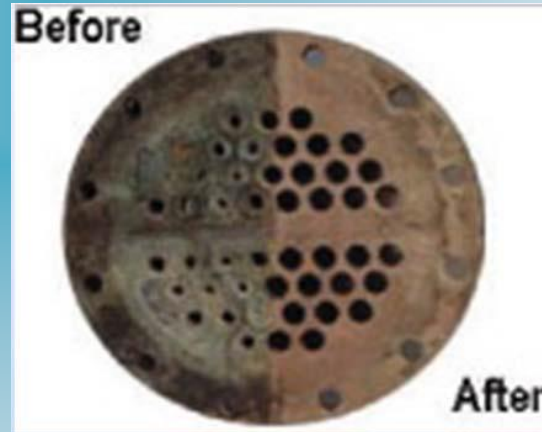


Galvanized sheet metal with White Rust

- Effect of White Rust
 - Equipment Corrosion starts
 - Premature failure of the galvanized coated metal
- The absence of proper conditions the zinc layer will corrode quickly and can get stripped away to expose the underlying steel to the environment

Fouling

- **Fouling** is the depositing or accumulation of particles or material on mechanical systems



- Effects of Fouling
 - Reduce heat transfer efficiencies
 - Decrease fluid flow
 - Increases system pressures
 - Increases operational cost

Microbiological Growth

- **Microbiological growth** is the amplification or multiplication of microorganism.
 - **Bacteria's of Concern**
 - *Pseudomonas*
 - *Desulfovibrio*
 - *Clostridia*
 - *Beggiatoa, Sphaerotilus, Gallionella*
 - *Legionella*
- Fungi
- Algae
- Protozoa

Microbiological Growth Environment

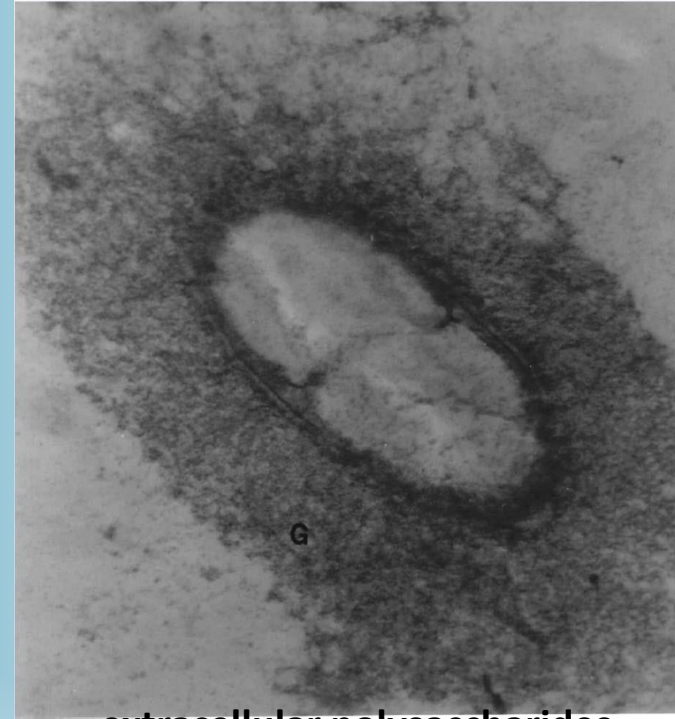
- Nutrients (phosphate, nitrogen, organics)
- Ideal temperature (70 to 140 F)
- Ideal pH (6.0 - 9.0)
- Proper Atmosphere (oxygen-aerobes/no oxygen-anaerobes)
- Sunlight – Algae
- Wood - Fungi

Microbiological Growth Concerns

- Biofouling
- Heat Transfer Resistance
- Microbiological Induced Corrosion
- Cooling Tower Fill Fouling
- Wood Decay
- Human Health Concerns

Pseudomonas Bacteria

- Gram negative rod One or more polar flagella, providing motility
- Aerobic, although some species have been found to be facultative anaerobes (e.g. *p.Aeruginosa*)
- Non-spore forming
- Positive catalase test



extracellular polysaccharides
(slime)



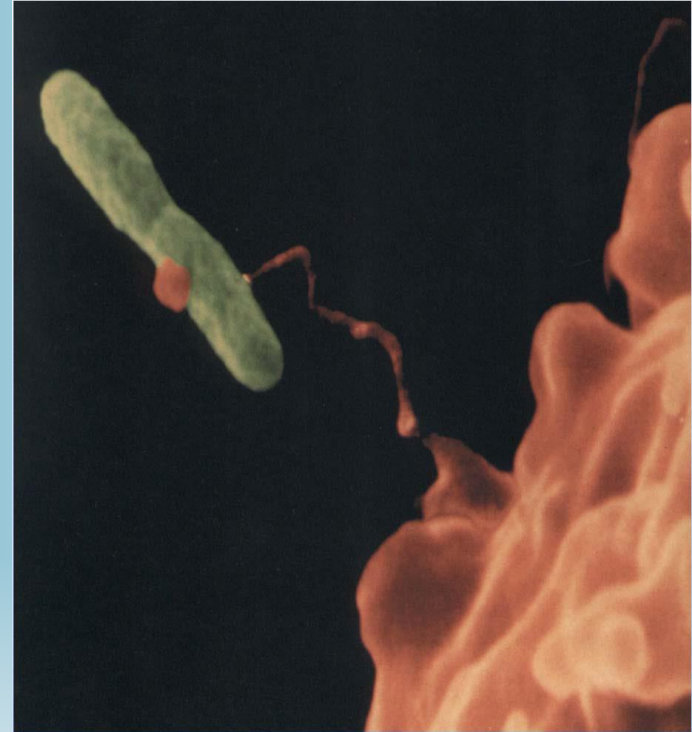
Legionella Pneumophila

- Gram negative rod
- Ubiquitous organism, present in most surface and ground waters
- Survives temperatures 35 F to 140 F (70 to 110 F best)
- 14 serogroups (strains) identified, serogroups 1, 4 and 6 most commonly associated with human illness.

Disinfection-Quarterly Legionella test by the mentioned Lab is required on each Cooling Tower. Lab result shows existence of Legionella more than 1 (one) C.F.U.s the Contractor shall immediately treat the cooling tower water and test every 15 days until the full recovery of 0 (zero) C.F.U.s.

Dipslides must be incubated at 35 C for 48 hours.

For Legionella emergency disinfection purposes, an initial 50 ppm free chlorine residual is recommended followed by subsequent repeats of 10 ppm free chlorine residual over a prescribed disinfection period (Reference: CDC**)



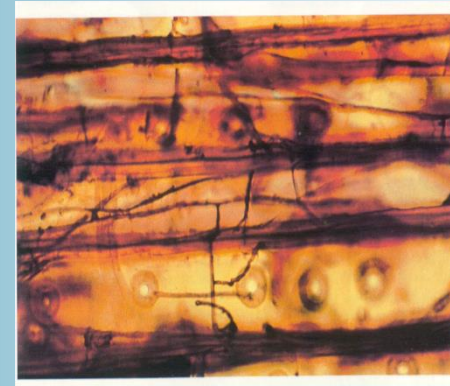
Fungi

Wood Fungi

- **Soft rot Fungi**- surface attacks, grow on wood in damp environments.
- **Brown-rot fungi**- wood is brown and shows brick-like cracking
- **White-rot fungi**- are more numerous than brown-rot fungi, the wood takes on a 'fibrous appearance and tends to go slightly lighter in color
- **Molds (Non Wood Decaying Fungi)**-These organisms could indicate a moisture level in the wood high enough to also support the growth of wood decay fungi. Molds also can increase the capacity of wood to absorb moisture, opening the door for an attack by wood decay fungi.



<http://archive.bio.ed.ac.uk/jdeacon/FungalBiology/woodrots.htm>



Song and Trulear, CTI, 1987



http://woodwildpark.org/fungi/White-rot_Fungus.htm



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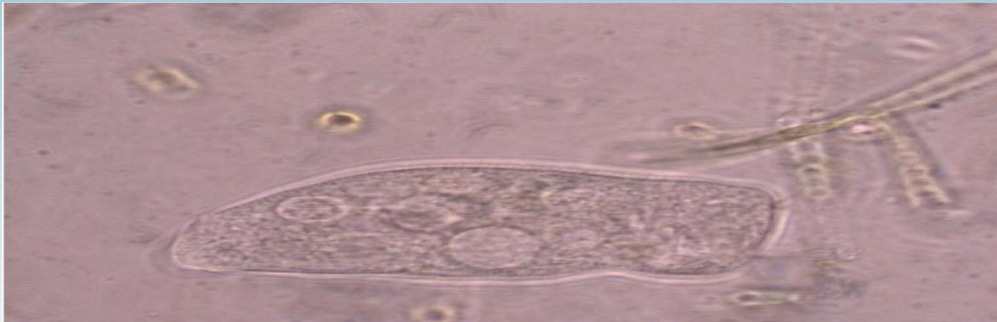
Algae

- Require sunlight
- Found on open cooling tower deck
- Plugs distribution nozzle
- Metabolism provides nutrients for bacteria and fungi
- Dead matter can cause fouling and support for other biological life



Protozoa "little animal."

- Ciliates which are generally the largest protozoa
- Amoeba can live in human intestines. It feeds on red blood cells and causes a disease known as dysentery
- Flagellates which are generally the smallest of the protozoa
- Protozoa have been found throughout aqueous environments and soil, an important food source for larger creatures and the basis of many food chains.
- Plays a role in controlling bacteria populations and biomass. Is an important food chains for micro invertebrates
- Parasitic such as malaria parasites.



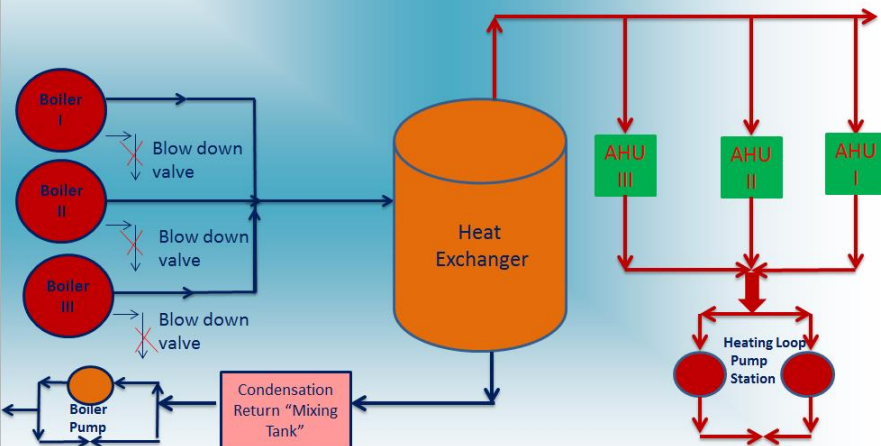
Tools of Defense

- Scale control
- Corrosion control
- Fouling control
- Microbial control

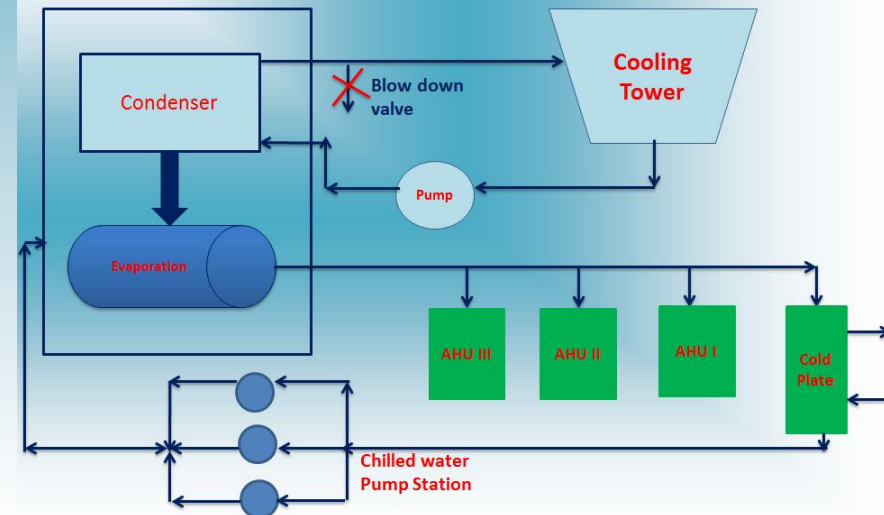
Scale Control

- Blow down removal of water from a boiler or Cooling Tower, to reduce water in the system with high concentrations of dissolved minerals in the water increased by evaporation and replaced by water with lower dissolved solids.
- These solids are present because of make-up water contamination, by internal chemical treatment precipitates, or by exceeding the solubility limits of otherwise soluble salts.

Tools of Defense



Tools of Defense



Corrosion Control

- Inhibitors are substance that retards or stops chemical reaction.
 - Anodic Corrosion Inhibitors (form a protective oxide film on the metal surface).
 - Orthophosphate
 - Nitrite
 - Molybdate
 - Silicate
 - Cathodic Corrosion Inhibitors (form insoluble precipitates that can coat and protect the surface. Precipitated films are not as tenacious as passive films and take longer to repair after a system upset.)
 - Zinc
 - Polyphosphate
 - Phosphonate
 - Triazole
 - Stabilized Phosphate Corrosion Inhibitors
 - Polyphosphate
 - Phosphonate
 - Orthophosphate
 - Closed Loop Water Chemical Treatment
 - Nitrite/Azole
 - Nitrite/Molybdate/Azole
 - Molybdate/Azole
 - Molybdate/Phosphonate
 - Silicate/Azole

Microbial Control

- Minimize exposure of cooling tower decks to sunlight
- Prevent **nutrients** entering cooling tower
- Oxidizing Biocide
 - Liquid
 - Oxidizing Biocides
 - Non-oxidizing Biocides
 - Solid
 - Oxidizing Biocides
 - Non-oxidizing Biocides
- Selecting Biocide
 - Type of Microorganisms
 - Sensitivity to pH
 - Life cycle time in system
 - Type and extent of program
 - Types of Contaminants (i.e. Bacteria, Fungi, Algae, Protozoa, Etc...)

Microbial Control

- Fluid Micro Biocides:
- Oxidizing Biocides
 - Chlorine
 - Bromine
 - Chlorine Dioxide
 - Glutaraldehyde Liquid Micro Biocides
 - Ozone
- Solid Micro Biocides:
- Oxidizing Biocides
 - Chlorine Tablets (Calcium Hypochlorite)
 - Trichlor Tablets (Trichloro-s-triazine-trione)
 - Bromine Tablets or Granules (Bromo-Chloro-Dimethylhydantoin)
- Non-oxidizing Biocides
 - Isothiazolin
 - Glutaraldehyde
 - Dibromo-nitrilopropionamie (DBNPA)
 - Carbamate
 - Quaternary Amines
 - Terbuthylazine
- Non-oxidizing Biocides
 - Dibromo-nitrilopropionamie (DBNPA)

Water Treatment Elements

- Chemical Feeding Equipment
- Testing Tools
- Safety Equipment

Chemical Feeding Equipment

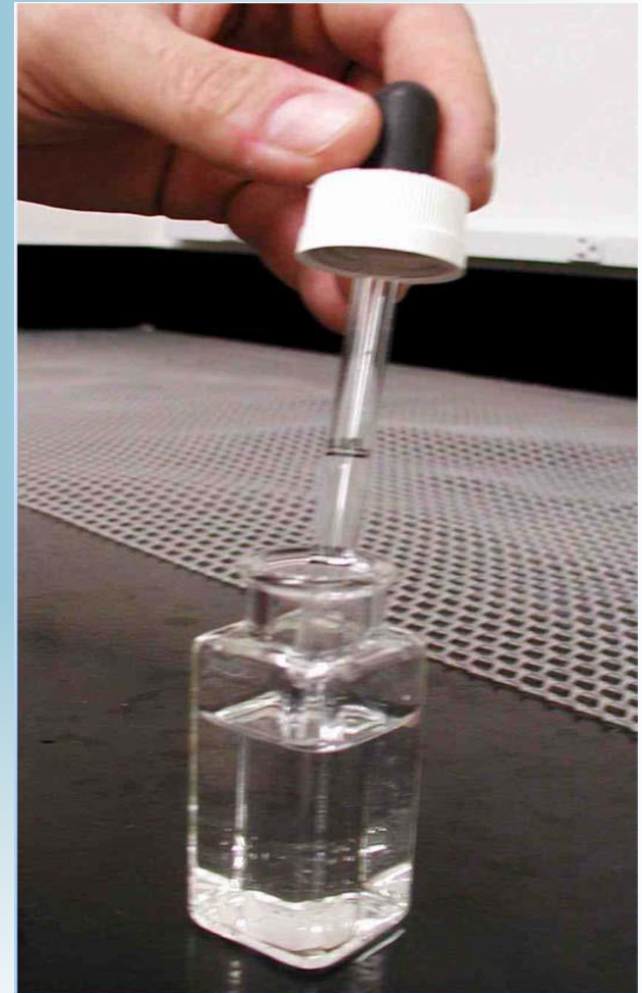
- Chemical Pot Feeders
- Pumps
- Chemical controller
- Chemical Solution tanks, crates, racks
- Agitators
- Liquid Level Switches
- Water meter
- Valves, tubing

On-line Polymer Analyzer



Cooling Water Polymer Test

- Three minute test
- Sequential reagent addition
- Absorbance measurement
- Measures total polymer
- Free polymer (0.45 μm) filter

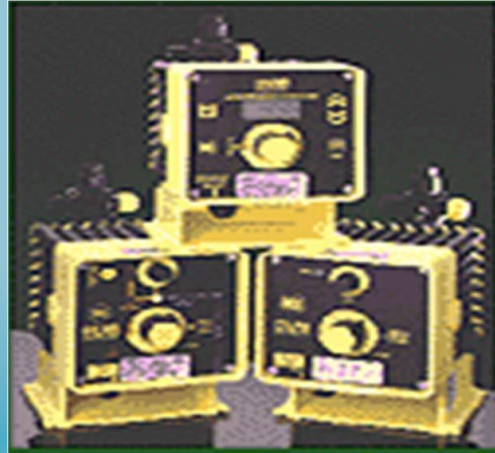


Chemical Feeding Equipment

Water
Treatment
Elements



LMI Conductivity
Controller



LMI Chemical feeding
pump



Chemical tank w/basin



Web based controller

Chemical Testing Equipment

- pH/meter
- Oxygen/meter
- Bio-count/slide
- Alkalinity/chemical strip
- Total hardness/meter
- Corrosion Test Coupon Assembly

Corrosion Testing Tools



Corrosion Coupon Rack



DIGI Titrator Alkalinity Tester



New Corrosion Coupon



Used Corrosion Coupon



Chemical Safety Equipment

- Safety Equipment's
 - Goggles, gloves, chemical crates



Goggles



Gloves



Chemical Crates

Benefits of Chemical Water Treatment

Benefits

- Improved performance decrease in energy consumption & operating cost by efficient heat transfers.
- Increase in system life expectancy.
- Minimizes risk of disease.
- Effective and is proven in different areas of application.

Most widely used treatment method & industry standard for the last 50 years.

Concerns

- Less environment-friendly than other methods
- Requires proper disposal of chemicals

Calculated Saving sample from Scale Treatment

- Energy Saving by scale control
 - Boiler
 - Fuel consumption = 450,000 million Btu of fuel
 - Operating time = 8,000 hrs
 - Rated Capacity = 45,000 lb/hr of 150 psig steam
 - Scale formed
 - 1/32nd of an inch thick
 - Normal Composition
 - Results in fuel loss of 2%
 - Savings
 - Price of energy - \$8.00/MMBtu
 - Annual Operating Cost saving
 - = 450,000 MMBtu/yr x \$8.00/MMBtu x 0.02 = \$72,000

Alternatives Chemical Treatment Methods

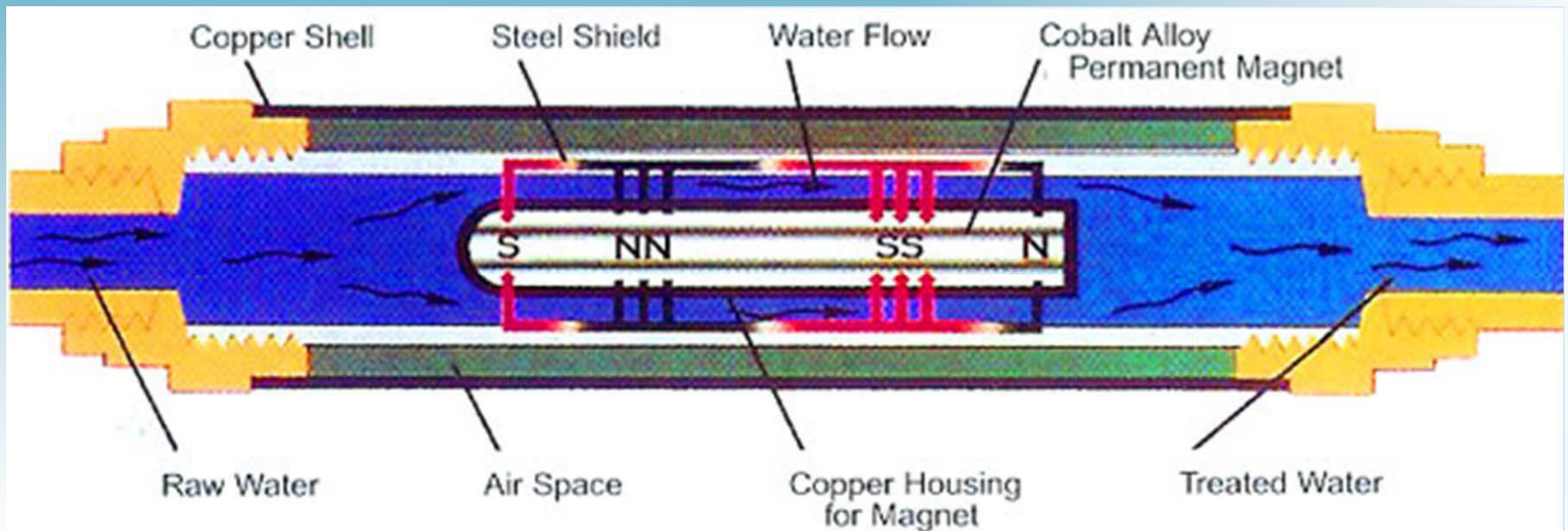
Non-Chemical Base Water Treatment Methods

- Magnetic
- Induced Electrical Field
- Electrostatic
- Electrolysis
- Ozone
- Hydrodynamic Cavitation

Magnetic Water Treatment

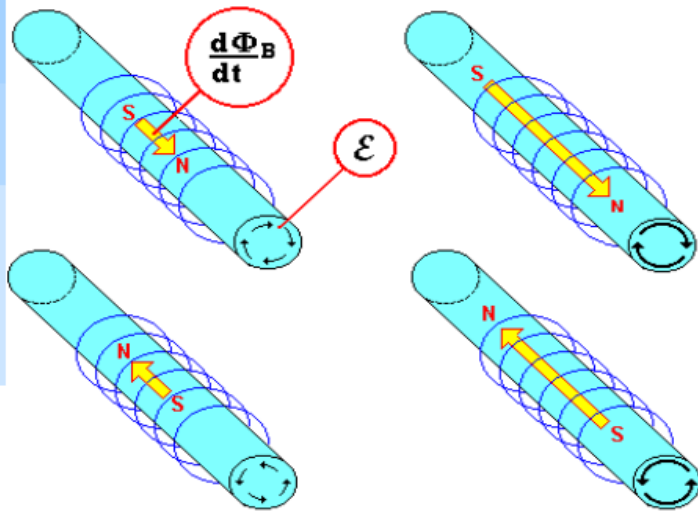
Magnetic Water Treatment

- Water subjected to a series of reversing-polarity, permanent magnetic field, prevents formation of scaling.
- Scaling forming ions start repelling each other.



Induced Electrical Field

The Dolphin--Faraday's Law



- The yellow arrows represent a time varying, longitudinal magnetic field that is constantly growing, shrinking and reversing direction. It is induced by a complex configuration of coils and circuitry.
- The changing magnetic field induces a circumferential electric field represented by the black arrows that constantly grows, shrinks and changes direction in the water inside the pipe.
- The electric field effects the surface charge and precipitation behavior of charged particles regardless of water velocity, temperature, pH or ion strength. The properties of the electric field are controlled by Dolphin circuitry.



Clearwater Systems



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Electrostatic Water Treatment

- Zeta Rod patented capacitor-based technology electronically disperses bacteria and mineral colloids in aqueous systems
- Colloids in water systems become components of the capacitor receive a strong boost to their natural surface charge altering double-layer conditions that govern particle interactions.
- Bacteria are unable to attach , absorb nutrition, or replicate into colonies. Existing biofilm hydrates excessively, loses bonding strength and disperses.

Electrolysis Water Treatment

The Basic Electrolysis Process

Sodium chloride salts (NaCl) are added to pure water

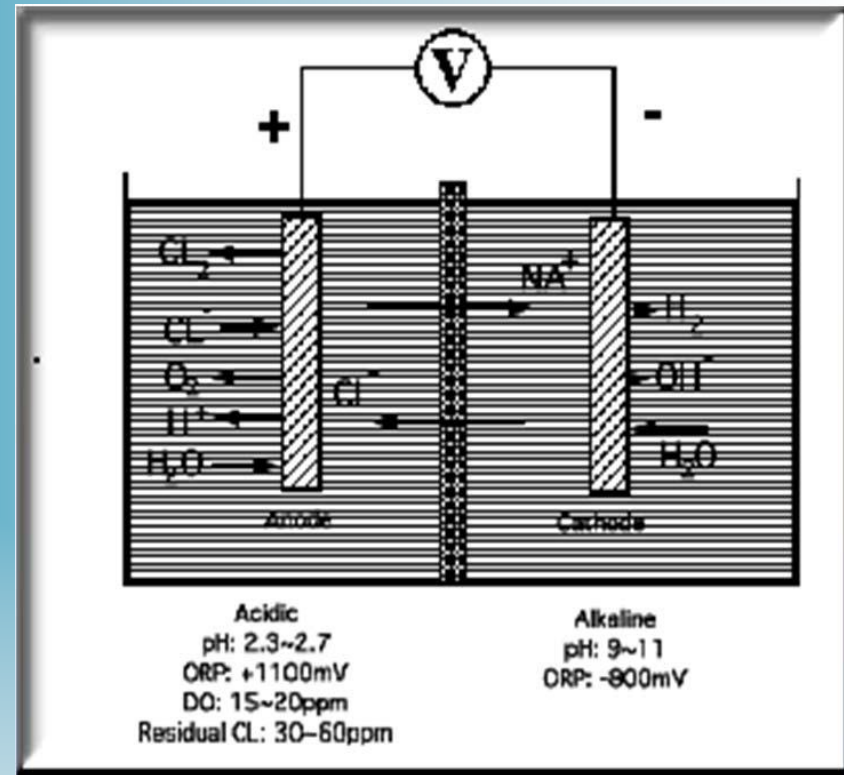
Voltage is applied across anode and cathode

Cathode area produces alkaline (reducing) water

Anode area produces acidic (oxidizing) water

ChlorFree®

- The patent pending design delivers copper silver ions to the recirculating water for biological control and removes dissolved minerals from the water.



<http://www.chlorfreewater.com/WaterPurification-2.htm>

Ozone Water Treatment

Ozone (O_3) oxidizes many materials into insoluble oxides that can precipitate or settle out

(Generally all are filterable). Occasionally some are foamy (so can be skinned).

Advantage:

- Treats Bacteria, including iron bacteria
- Removes Heavy metals such as iron and manganese
- Treats organic contaminants such as tannin and algae
- Treats microbes such as Cryptosporidium, Giardia and Amoebae
- Treats all known viruses
- Treats Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Disadvantage:

- Little residual for distribution systems.
- Filtration required virtually all cases.
- Corrosive as a gas and in solution (that's how it works).
- Reputation of being expensive.
- Not yet well understood by many designers and regulators.
- Ozone cannot be used to reduce calcium and magnesium hardness

Hydrodynamic Cavitation's Water Treatment (VRTX)

Non-Chemical
Base Water
Treatment
Methods

Hydrodynamic Cavitation's Produced by pressure variations in a flowing liquid due to the geometry of the system

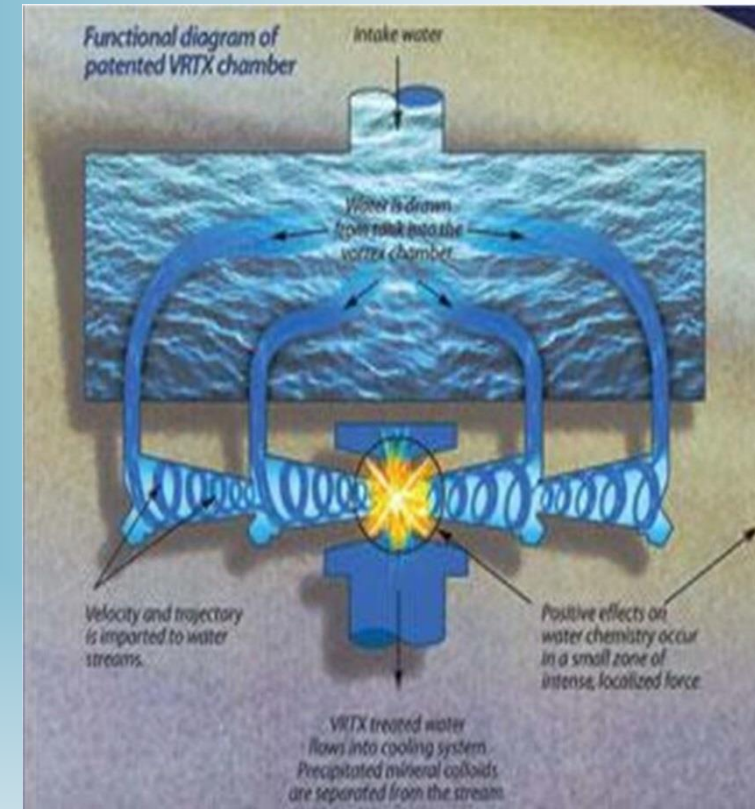
Cavities are formed when the pressure is lower than a critical value

Cavities grow in low pressure zone

Cavities collapse as pressure increases

Cavitation results in

- High temperature micro-zone
- High-energy micro-jets
- Decomposition of water molecules
- Acceleration of chemical reactions



Georgia Tech approach to Hydronic systems water treatment

Question ?



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