GE Power & Water
Water & Process Technologies

Campus Energy 2016
Austin, TX

Effective Water Treatment for Chilled and Heating Water Systems for Thermal Distribution Systems

Jim Gleason

GE Water Senior Product Applications Engineer

February 9, 2016

Definition of Closed Water System

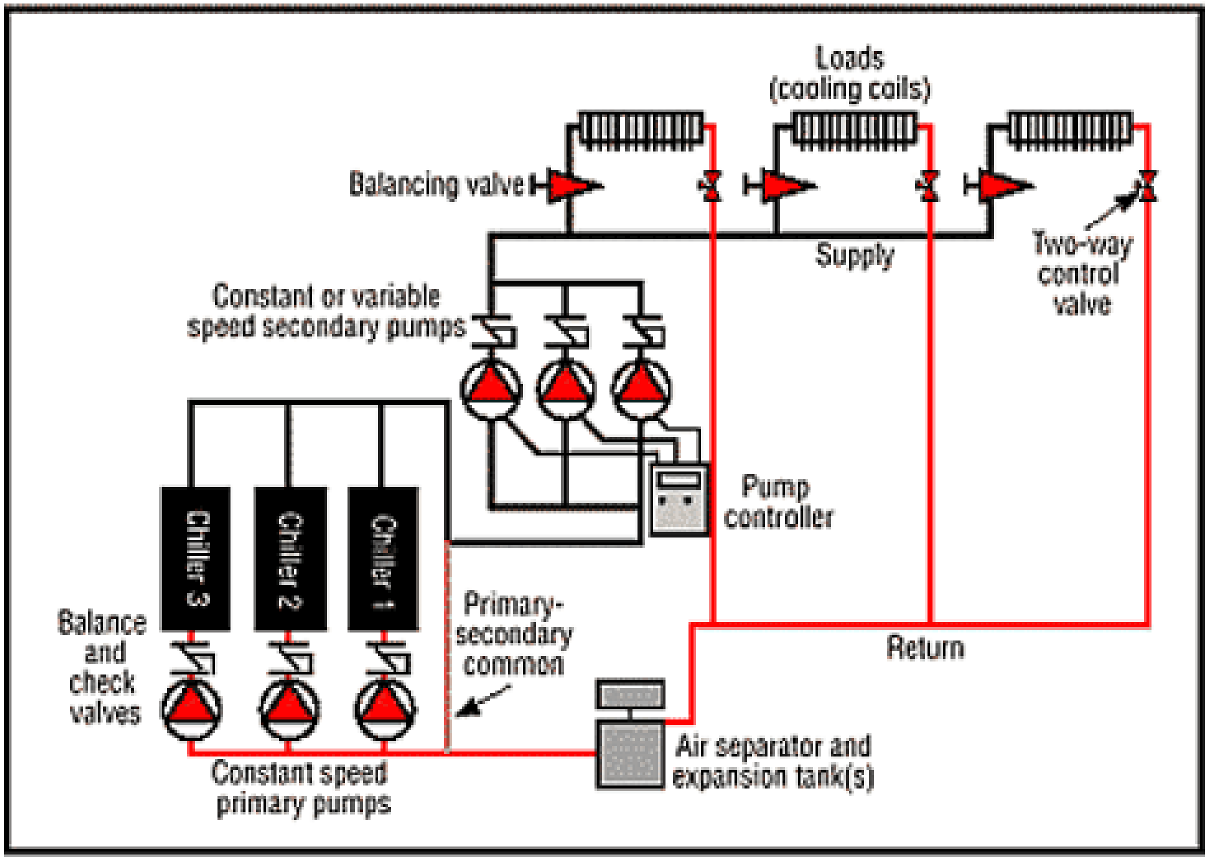
Not Open to Atmosphere

No Water Evaporation

Designed for Minimal (less than 1%) water losses

Used to transport Chilled or Heating Hot Water or both with two pipe systems

Typically treated with higher dosage levels of chemical treatment.



Still subject to corrosion and scale despite being "closed"

imagination at work

Closed System (typical assumptions)

- Extremely low water losses due to evaporation or blowdown
- High quality makeup (softened at minimum)
- High inhibitor levels (to achieve lowest possible mpy)
- Temperature ranges as high as 350°F
- Water, glycol, and brine systems

What happens when we assume?

Closed Loop System Monitoring

- Iron (Ferrover Method/FerroMo if molybdate inhibitor)- number one test to run
- Chemical residuals (NO_2, NO_3, NH_3, MoO_4, TTA)
- System parameters, such as pH and conductivity
- TAP analysis and verify that metals present reflect the system metallurgy
- Water losses and leaks
- Microbiological activity, both sessile and planktonic
- Corrosion coupons
- Outlet water temperatures on critical exchangers
- Stagnant conditions

Condenser Approach Temperature

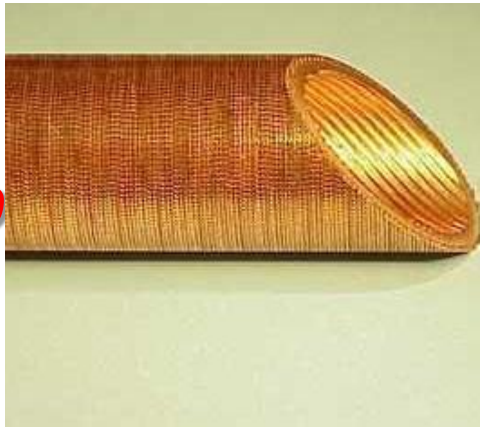
When Tubes Are Dirty

Insulation Effect – Scale, Fouling, Bio

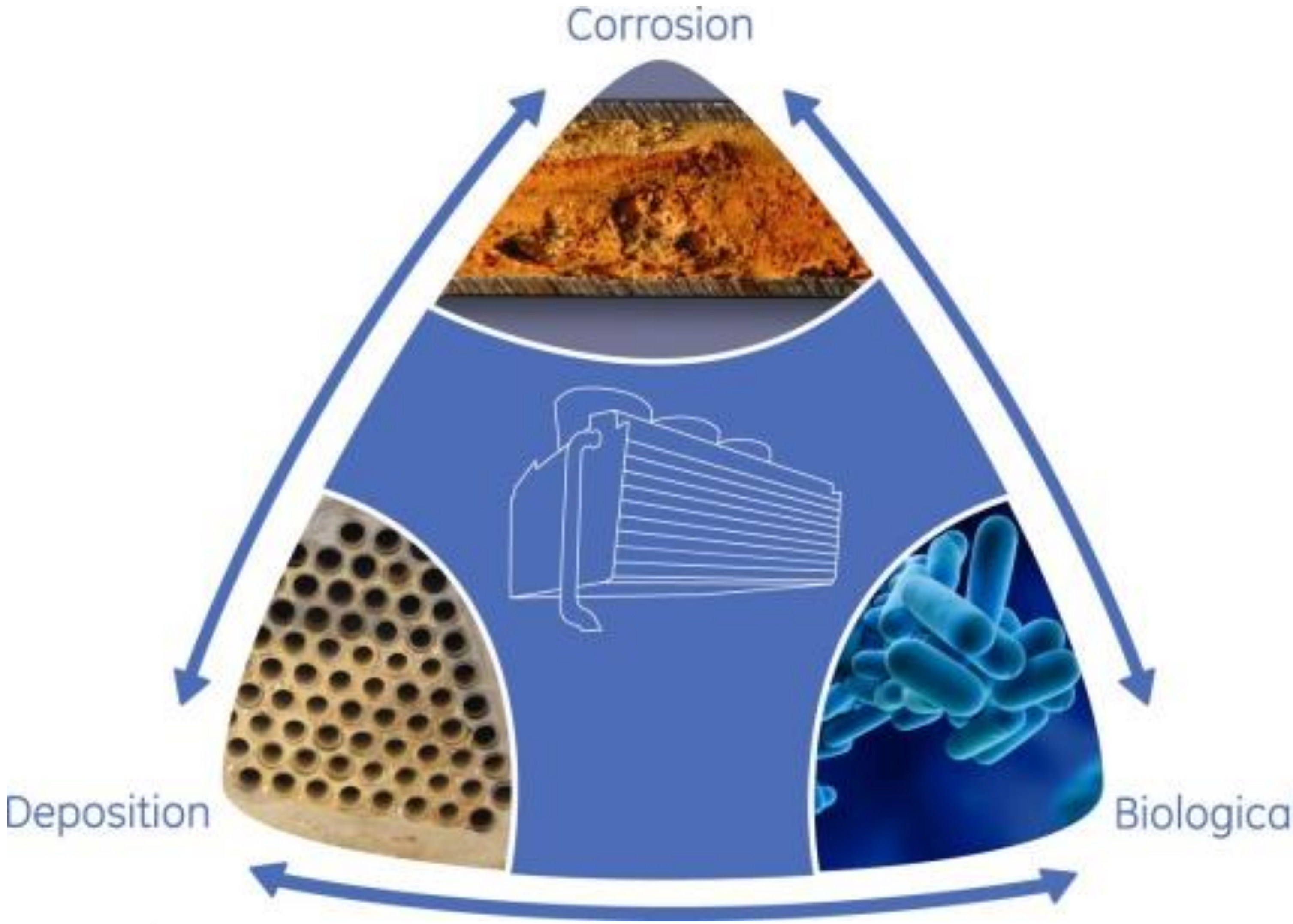
More energy to raise water temp

Efficiency loss **as high as 40%**

Problem amplified with Enhanced Tub



The Water Treatment Triangle



imagination at work

Ranking the three legs of the triangle

Corrosion first among equals

Why? Because corrosion by-products inhibit heat transfer and promote MB growth, which also inhibits heat transfer

Deposition easiest of three to treat- to stop scale, either remove calcium via softening/demin/RO, or use scale inhibitors like phosphonate/AEC (acid for closed loop pH control not usual)

SSF excellent to minimize deposition of suspended solids- minimize “bleed/feed”

Biological easiest to get out of control

Biocides less lethal than in past

Biocides also either expensive or indiscriminate

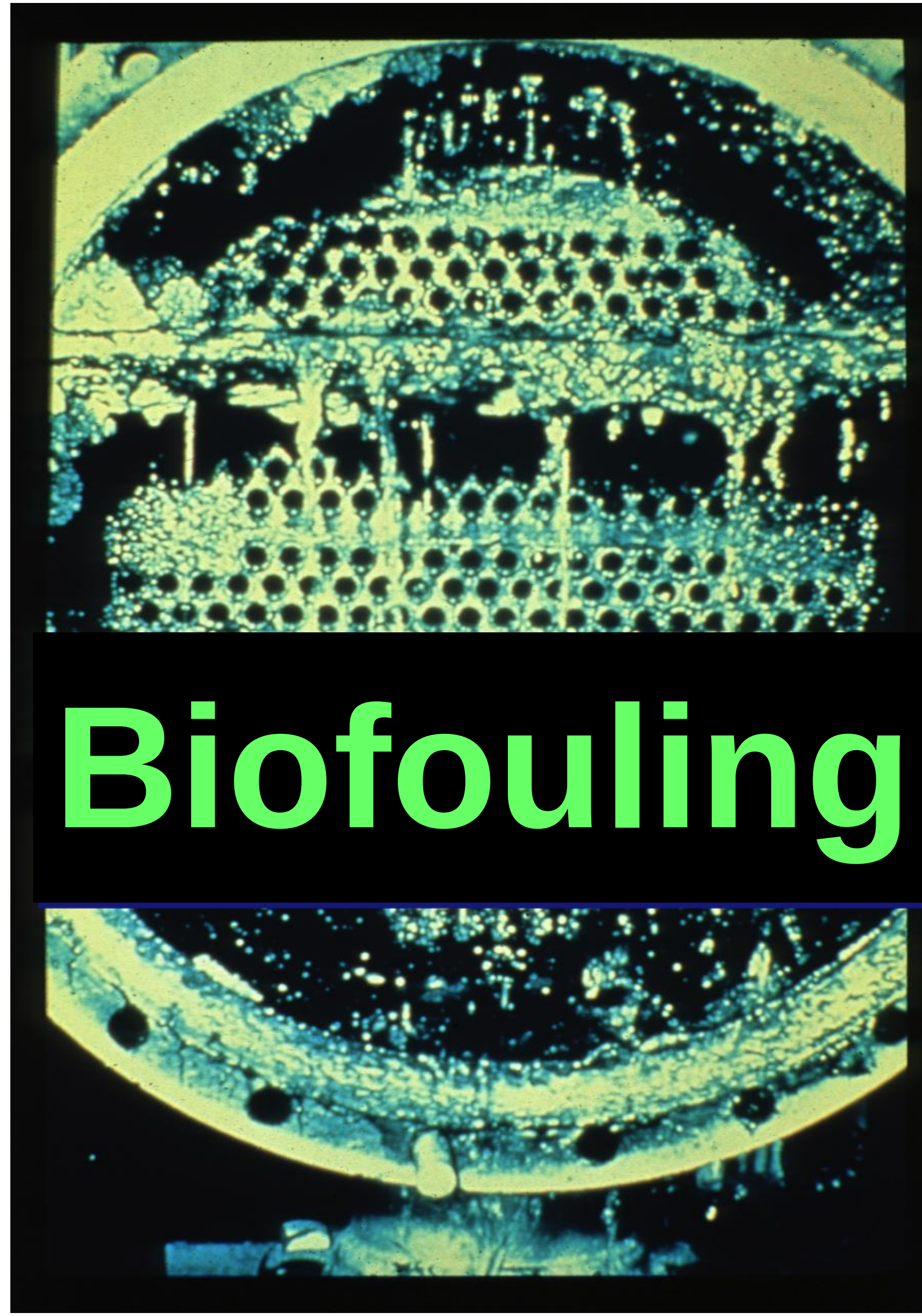
Must rely on monitoring to avoid problems beforehand

Corrosion by-products: Disproportionate Volume

For 2000 yards standard weight pipe, 20 mpy corrosion for 6” diameter pipe will generate 5 tons hydrated iron each year (40 ft3/year volume)

20 mpy for 24” diameter pipe will generate almost 25 tons hydrated iron each year (200 ft3/year volume)

Biofilms



The Tangible Impact

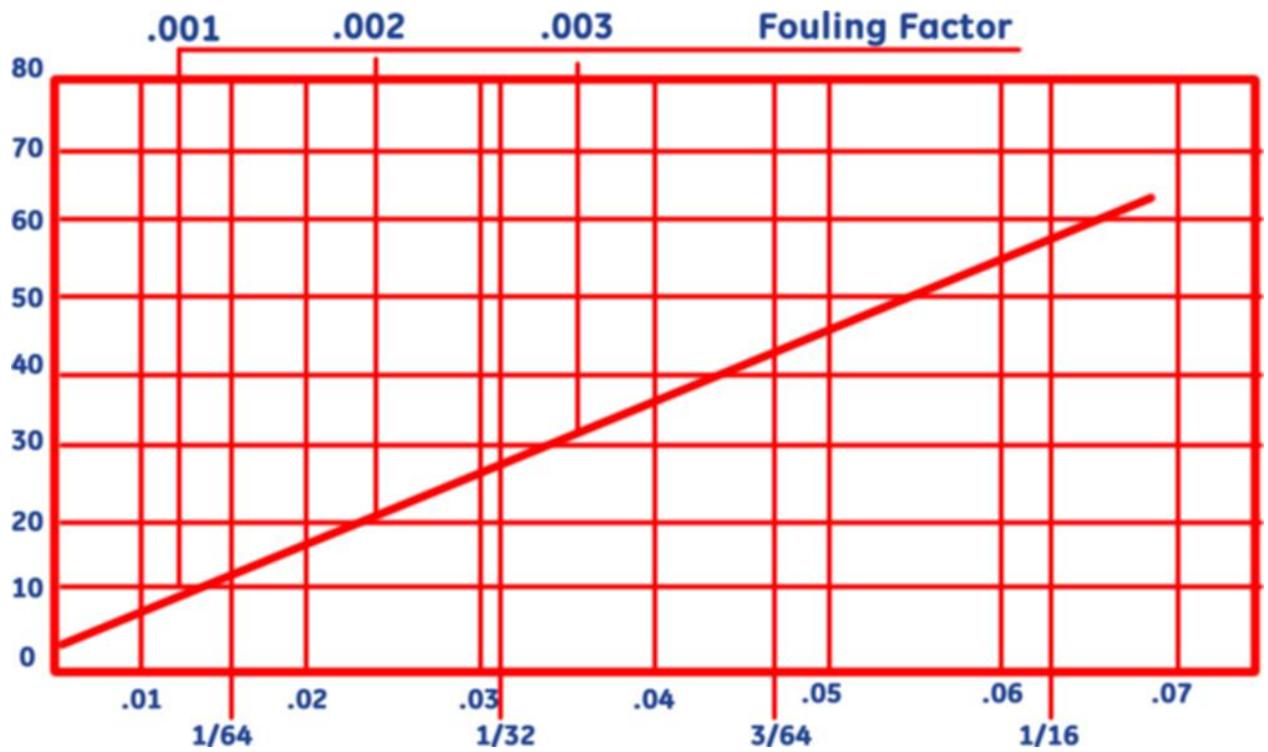
- Microbial films consist of water.
- Trapped water →Stagnant water
  Poor conductor of heat
  Biofilm - great insulator

1 mm of biofilm **= *83 mm Steel Exchanger Tube***

Effect of Condenser Scale Thickness

On Power Consumption (Clean Tubes)

Percent Added Power Consumption



Condenser Scale Inches

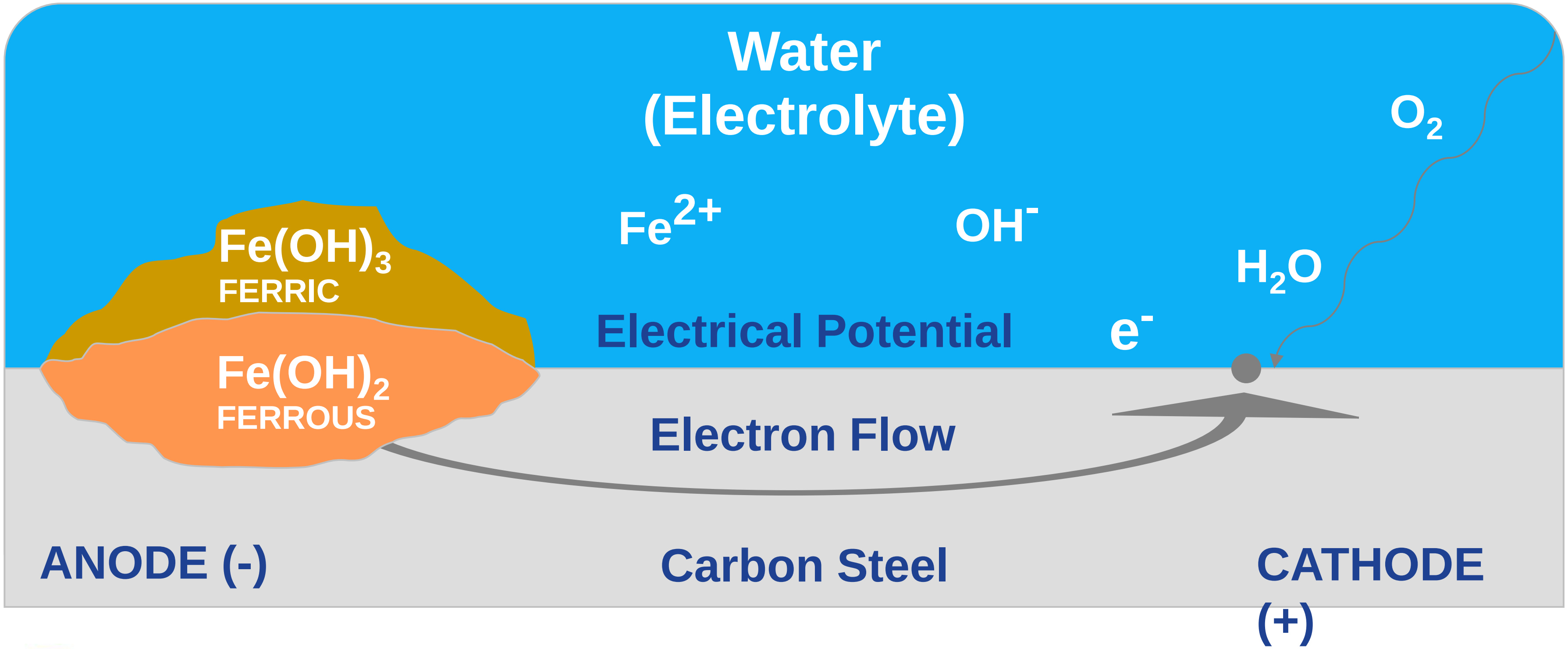
Key Performance Summary

Chillers - 40% to 60% of Building energy consumption.

Chillers can operate inefficiently
without being obvious

Tube fouling - Main cause of efficiency loss

Basic Mild Steel Corrosion Cell



GALVANIC CORROSION BASICS:
concern for mixed metallurgy systems

Stainless Steel (Passive)

Titanium

Bronze

Copper

Brass

Stainless Steel (Active)

Cast Iron

Mild Steel

Aluminum

Zinc

Magnesium

Cathodic -
More Easily
Protected
(More Noble)

Anodic -
More Easily
Corroded
(Less Noble)

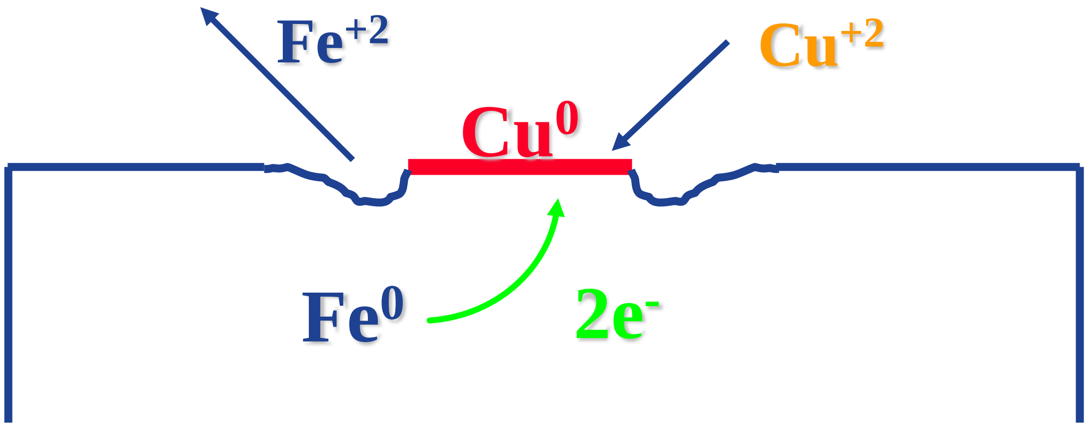
imagination at work

GALVANIC CORROSION
(COPPER INDUCED)

Galvanic Corrosion

Example - Copper Plating on Steel

$$Fe^{O} + Cu^{+2} \dashrightarrow Fe^{+2} + Cu^{O}$$



Corrosion Monitoring

Corrosion Coupon Assembly

•Corrosion coupon monitoring remains the least expensive method; insertion probe also

option

•Every closed system should be equipped with multiple metallurgy coupon sites

Acceptable Corrosion Rate Standards:
Closed Chilled Water Loops

Coupon Metallurgy	*Excellent Result	*Good Result
Carbon Steel	<0.2 MPY	< 0.5 MPY
Admiralty	< 0.1 MPY	< 0.2 MPY
Copper-Nickel	< 0.1MPY	< 0.2 MPY
Aluminum	< 0.2 MPY	< 0.5 MPY
Galvanized	< 0.25 MPY	< 0.5 MPY

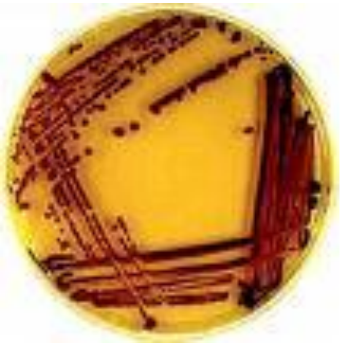
* No pitting

Biological Monitoring

ATP

Dip slides

Aerobic Count Plates (Petri Dish)



Microbial Guidelines: *Closed Systems*

MB count level within a system (cfu/ml)	Biocide treatment regimen
$>10^7$	Biocide failed to provide protection
10^5 - 10^6	Unsatisfactory biocide control
10^3 - 10^4	Biocide control satisfactory
$<10^2$	Excellent biocide control

MB monitoring: bulk counts not enough

Must look for sessile (surface) organisms; filters/strainers perfect "host" structures

Bulk organisms in transit between surfaces

Organisms secrete biofilms to control environment

Negative interplay between corrosion and bio-loading (lots of free "housing")

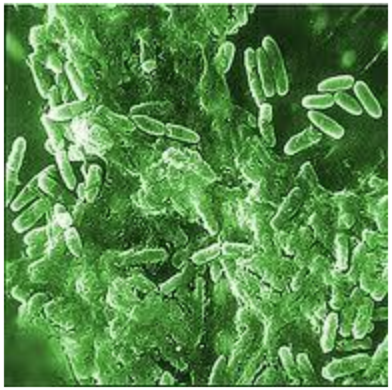
MB count 10-100x higher at surfaces than bulk

Bacteria and Bio-Fouling Inhibition

Bacteria of concern in closed systems:

- Sulfate reducing bacteria (SRB's); damaging at very low cfu/ml counts, generate little ATP
- Nitrite reducing bacteria- same concerns as SRB's
- Pseudomonads

Pseudomonads biofilm



SRB induced corrosion

Factors Affecting Biocide Choice

- Concentration
- Temperature
- pH
- Compatibility with other treatments present
- ***Cost effectiveness (usually better to feed more less often)***
- Resistance/Immunity
- Broad spectrum of activity
- ***<u>Compliant with EPA End-Use Label Criteria</u>***

Scale Inhibition

Solutions

- Ensure treatment formulation includes scale control agents
- Monitor system chemistry closely
- In hard water areas soften the fill/makeup water
- If softened water used, review treatment chemistry

Filtration of Closed Systems

Routine Filtration for Closed Systems

•Large systems system turnover of 1 to 4 days

- Variable speed pumps - Reduce velocity and increase the tendency for deposition of debris—

Greatest Impact: Enhanced Tubes

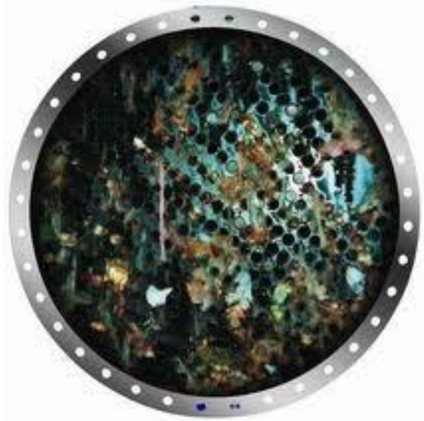
•Filter selection is determined as follows:

Filter Ft3/h =System Volume

Days per turnover x 24)

Monitor Particle size (PSA)

Filtration Various Types



- Strainers
- Dirt Separators
- Magnetic filtration
- Hydro-cyclones
- Disposable media filtration
  - Cartridges or bags
- Auto filtration
  - Multimedia (sand/anthracite)
- Membranes
  - Reverse Osmosis
    - Nano filtration
    - Ultra filtration

Cartridge filter

Bag filter

Chemical Solution

Select program based on water chemistry and application

Create/Replenish Passive Barrier

Special attention to copper inhibitor and monitoring

Regular Water Testing and Monitoring

Primary Closed System Inhibitors

- Nitrite (anodic inhibition)
- Molybdate (also anodic inhibition)
- Phosphonates (anodic inhibition)
- Alternative programs (cathodic inhibition)

Anodic vs. Cathodic Inhibition

Anodic inhibitors form gamma iron oxide film on metal surface (usual iron oxide film not adherent). Can achieve lowest possible mild steel corrosion rates. Must be maintained at minimum residual ***at all times***. Can be expensive program if MU to system elevated.

Cathodic inhibitors form barrier film at cathodic sites, using calcium hardness in water. Corrosion rates not as low as anodic inhibition. Require antiscalant. However, can be much less expensive if MU to system elevated.

Nitrite

Mechanism

- Anodic passivator
- Promotes passive iron oxide film

Advantages

- Low cost (compared to other anodic programs)
- Very effective on carbon steel
- Independent of oxygen
- Stable to 350ºF

Nitrite Challenges

- Effective only on carbon steel
- Oxidized to nitrate by MB, chlorine, and oxygen
- Passivation reaction produces ammonia
- Aquatic toxicity
- Brass stress corrosion cracking (O_2 present)
- Aggressive to solder
- High dosages required

  150- 1,200 ppm (500-700 ppm typical)

Molybdate

Mechanism

- Oxidizer
- Forms passive anodic film

Advantages

- Excellent MS corrosion inhibitor
- Mildly effective on Cu, Al, solder
- Excellent stability
- ***Compatible with oxidizers***

Molybdate

Disadvantages

- Higher cost
- Slow passivation, especially in low D.O.
- Not allowed by some discharge permits

Dosage

- 150 - 500 ppm as MoO_4

Molybdate / Nitrite Blends

Synergistic Combination

Provides Excellent MS Performance

- Low and high D.O.
- Stagnant conditions

Disadvantages

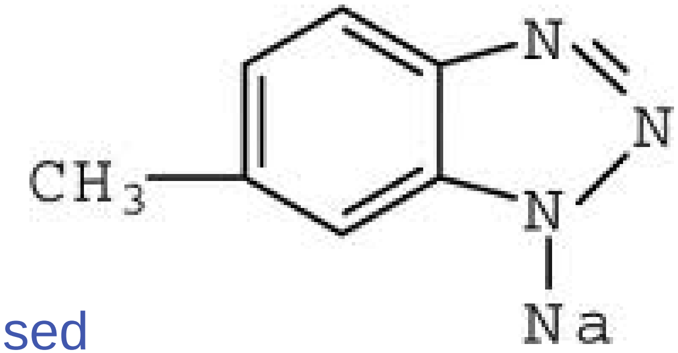
- Cost
- Still can be prone to MB reversion

Phosphonate

- All organic inhibitor blend w/dispersant
- Designed for low conductivity systems
- Low active concentration
- Excellent environmental profile
- Ideal for new or cleaned systems
  - 0.05-0.07 mpy on mild steel
  - 0.06-0.08 mpy on copper

  May remove existing corrosion by-product if system not clean

Copper Protection



Most used - azoles:

- Tolyltriazine (TTA) – most commonly used
- Benzotriazole (BZT) – commonly used
- Halogen Resistant Azole – unique properties
- Typically blended in with anodic inhibitor

- Increasing levels - sulfate and chlorides
- *Chemically bonds with copper and copper alloys* to create film, stable for 5 - 7 days
- Complex with Cu^{+2} preventing copper plating of Al and low carbon steel, subsequent aggressive pitting

High Makeup Systems

Closed System, But Has High Water Losses (>5% System Volume Lost/Day)

- Sliding scale for ortho-PO_4 residual

Inversely dependent on system pH and calcium level

- Can not use softened/demineralized/RO MU
- One drum blend should include pyro-PO_4 to “toughen up” cathodic barrier film
- Can not achieve lowest possible mild steel corrosion control
- Requires antiscalant to prevent CaPO4 deposition

imagination at work

Chemical Solution

Program based on water chemistry and application

Inhibitor	Pros	Cons
Molybdate	Effective with no breakdown/Cl2 OK	High Cost, Heavy Metal
Nitrite	Cost effective Works rapidly	Breakdown, bacterial food/conductivity
Phosphate	Low Cost	Effectiveness, Precipitation
Silica	Perceived as safe	Effectiveness, scale formation
Complex phosphate	Iron and scale removal	Breakdown, bacterial food

Microbial Control

Non-oxidizers typically used in closed systems rather than oxidizers- why?

- Oxidizers (cheaper) are indiscriminate- may oxidize corrosion inhibitor as well as organisms
- Non-oxidizers (more expensive) target specific organisms with minimal collateral damage
- In order to be applied as infrequently as possible, sessile monitoring maximizes results while minimizing costs.

Biocide selection for closed systems

Best to perform either on site or off site toxicant evaluation, incorporating sessile MB sample

Biocides can select out resistant MB strains over time

Toxicant evaluation allows optimization of existing program/identification of new program with respect to dosing amount

Monitoring allows optimization of existing program with respect to dosing frequency

Servicing a Closed Loop

Check Inhibitor Levels, Conductivity & pH Once/Month

- Compare with make-up vs. inventory
- Check the draw down on the pump

Bioscan or ATP Analysis Monthly

Check For SRB Bacteria

Inspect Coupons Quarterly, Analyze Annually

- 0.1 mpy for the most critical systems
- Up to 0.5 mpy (“soft cap”) - 1 mpy (“hard cap”) for less critical systems

imagination at work

Closed System Pre-Op Cleaning

Cleaning and ***Passivation*** of new piping surfaces
Acid cleaning not desirable vs. cleaning/passivation together

Proper water treatment is **essential** for

Removing oils/slag from manufacturing and construction

Protecting new pipe and creating a protective passive layer.

The precautions taken on Pre –Op cleaning

Will **add years** to Heat Exchanger/Chiller life

HVAC Chiller/Closed System Lay-up

Cleanliness of the heat transfer surfaces
Proper water treatment is **essential** for
maintaining top efficiency
minimizing corrosion.

The precautions taken on laying up (either wet or dry) will add years to chiller life and prevent shutdowns

Wet layup: biocide/biodispersant/2-3x normal inhibitor residual
Dry layup: vapor phase inhibitor

Chiller Performance Optimization –

What is Measured can be improved

Mechanical and Chemical Performance

- **Approach temps**
- **Evaporator**
- **Condenser and Chilled** KPI's monitored
- Routine **Microbiological Monitoring**

Thank You for your Attention

Questions ?