McIlvaine Hot Topic Hour

Boiler Feed & Cooling Water Treatment

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January 27, 2011

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Agenda

- Water Sourcing : Water Footprint

Wastewater, Recycle, Surface, Ground, Municipal, Rain

- Boiler Pretreatment (Low Pressure vs. High Pressure)
- Boiler Water Treatment Programs
- Cooling Water Treatment
- Consider Life Cycle Costs

Water Source

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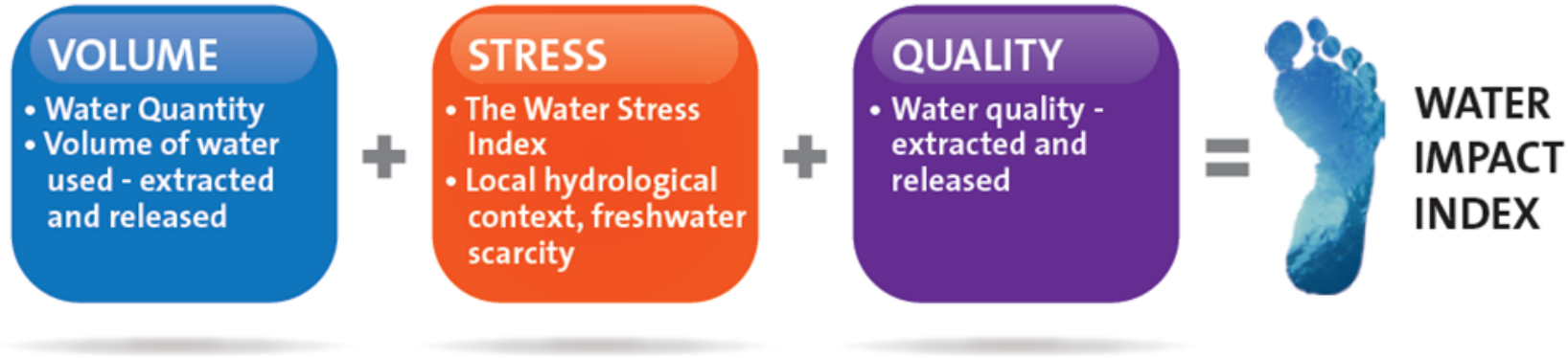
A new metric for assessing water impacts – the Water Impact Index (WII) developed by VE

The Water Impact Index accounts for…

… the impact on water resources generated by a human activity. It involves evaluating how other water users (both humans and ecosystems) could potentially be deprived of this resource…

…expressed in m^3-WII-equivalent



Drivers for Water Source and Usage

- Corporate image
- Corporate social responsibility
- Business risks related to :
  - Freshwater shortage for own operations
  - Freshwater shortage in supply chain
- Financial risks related to tensions on water's prices

Water Impacts… Much More Complex

- Volume of water used
  - Water extracted
  - Water released
- Water quality
  - Water extracted
  - Water released
- Local hydrological context
  - Freshwater scarcity
- Resource type
- Selection of Treatment Processes

Boiler Pretreatment Equipment & Processes

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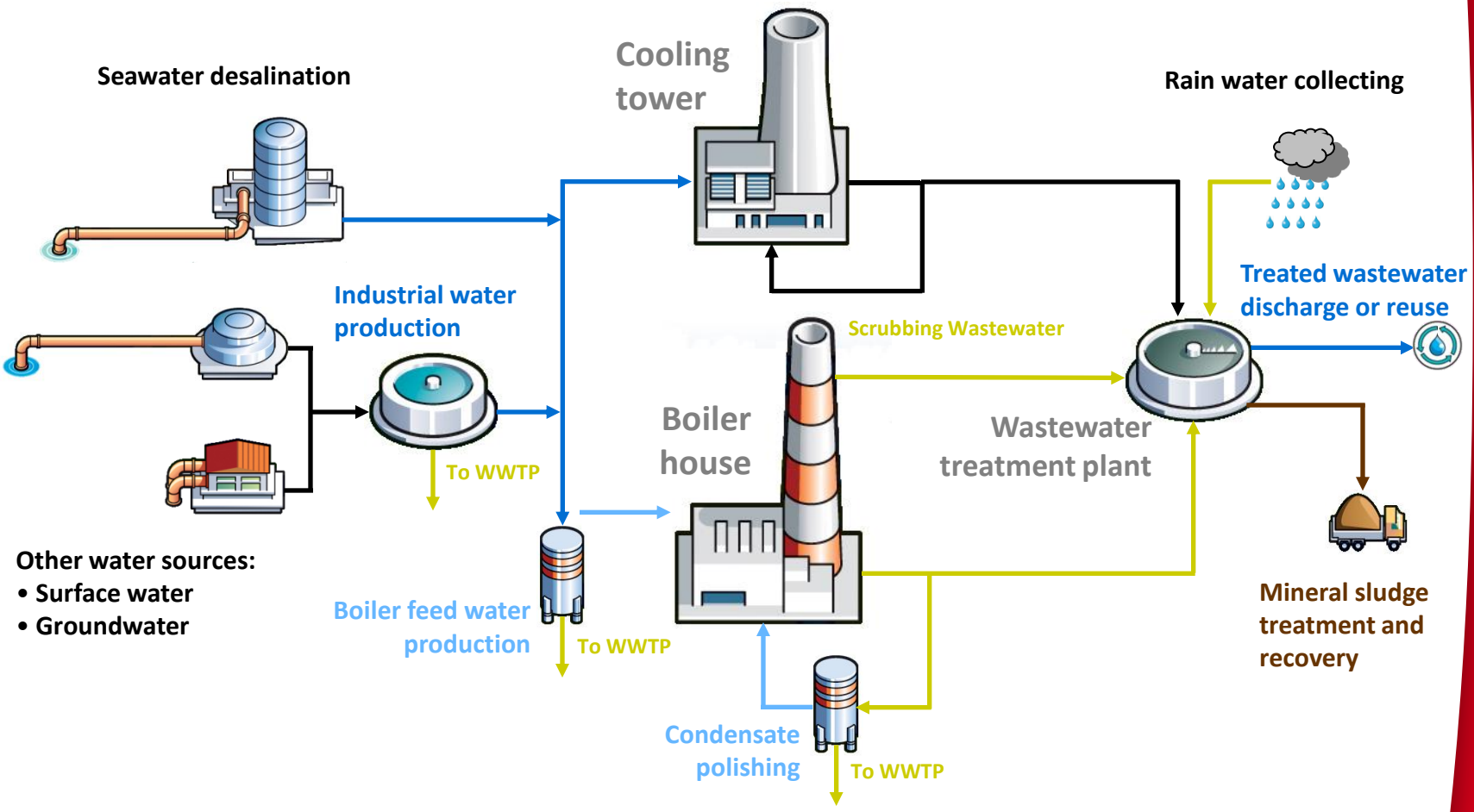
Pretreatment

- **Low Pressure Boilers:** Goal should be good external treatment, but can use internal treatment chemicals to manage deposits.
- **High pressure boilers** (> 900 psig) should use very high purity feedwater. Ideally, there should be no reason for precipitation-type internal treatment chemistry programs since there should be nothing to precipitate. Goal is to minimize corrosion and have high steam purity.
  - **Feedwater** will be demineralized by ion exchange demineralizers, RO, two pass RO, or EDI.
  - **Feedwater** will approach 0.5 µS or less.

Water Use in Power Generation Process Flow Diagram



Boiler Pretreatment Selection Guidelines

A. **Technical Factors:** impurities, influent water changes, boiler pressure and design, steam purity

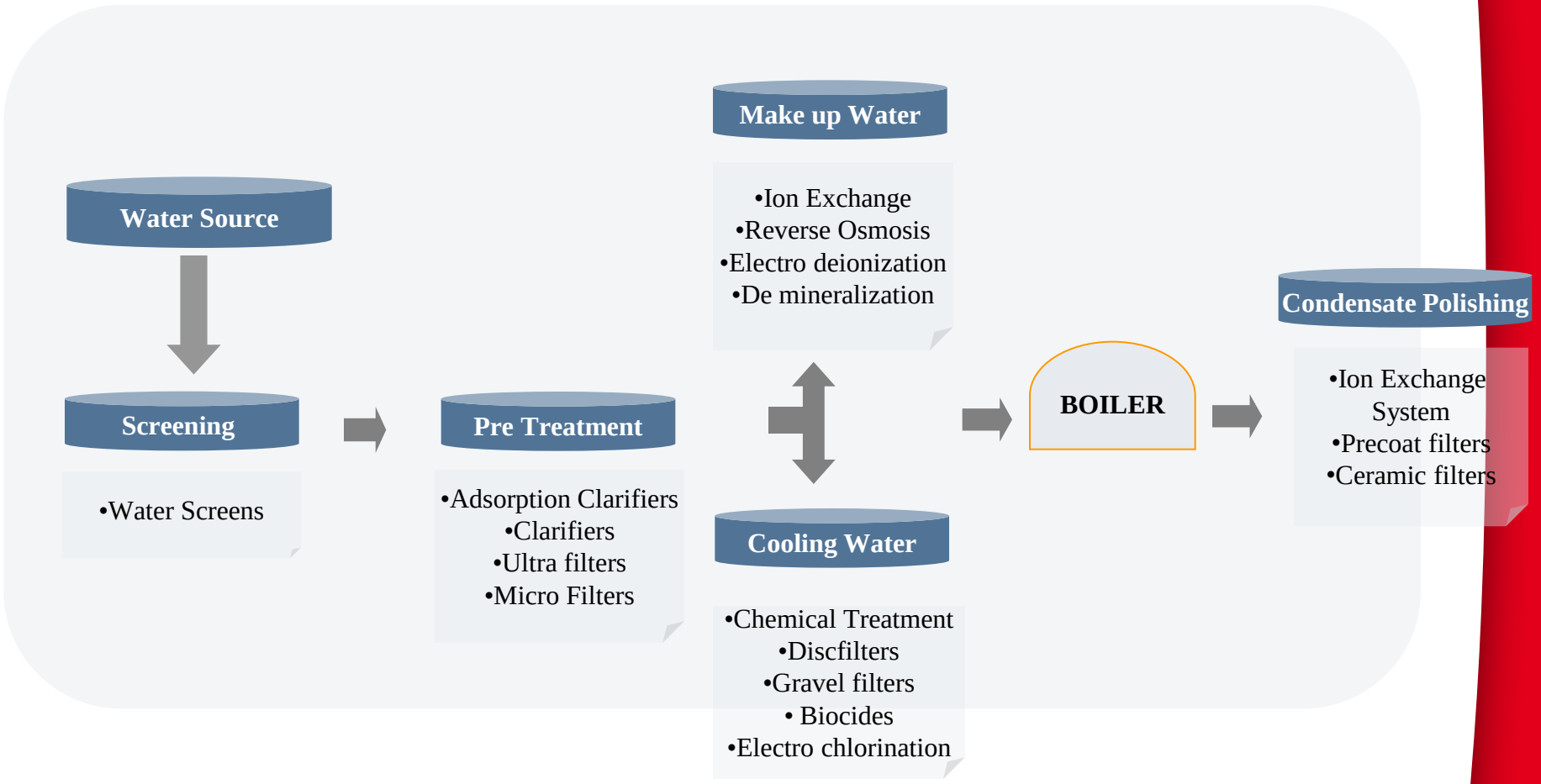
B. **Operational Factors:** manpower & competency, continuous or intermittent, consistency, reliability, internal treatment chemistry

C. **Economics:** capital cost, operating cost, life-cycle cost, energy consumption, water footprint

D. **Space Requirements:** footprint now, expansion room, inside or outside

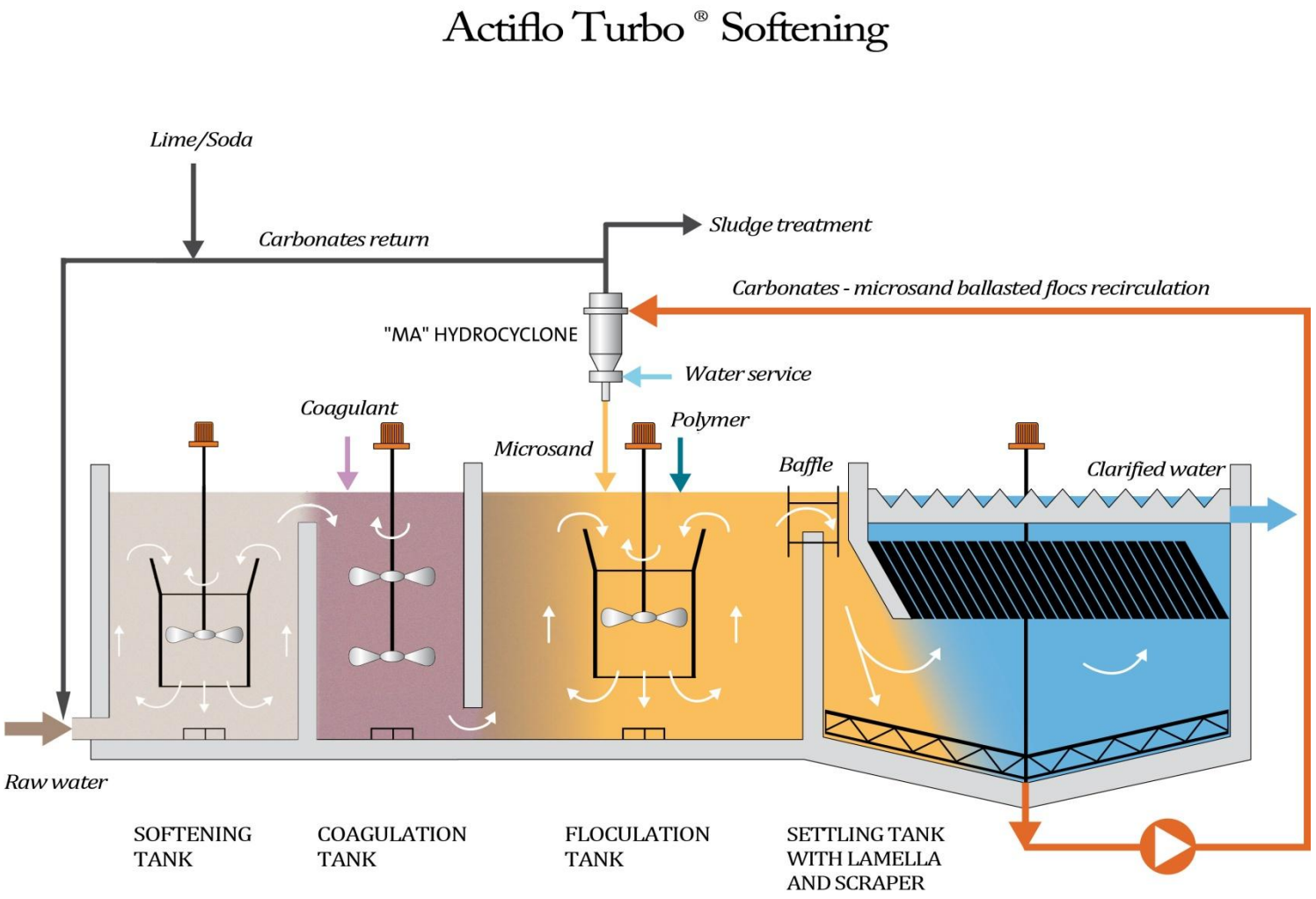
Technology Perspective – Key Technologies in the Water Treatment Segment

Opportunities for Water Management in Power Plants: Process Water Treatment Technologies

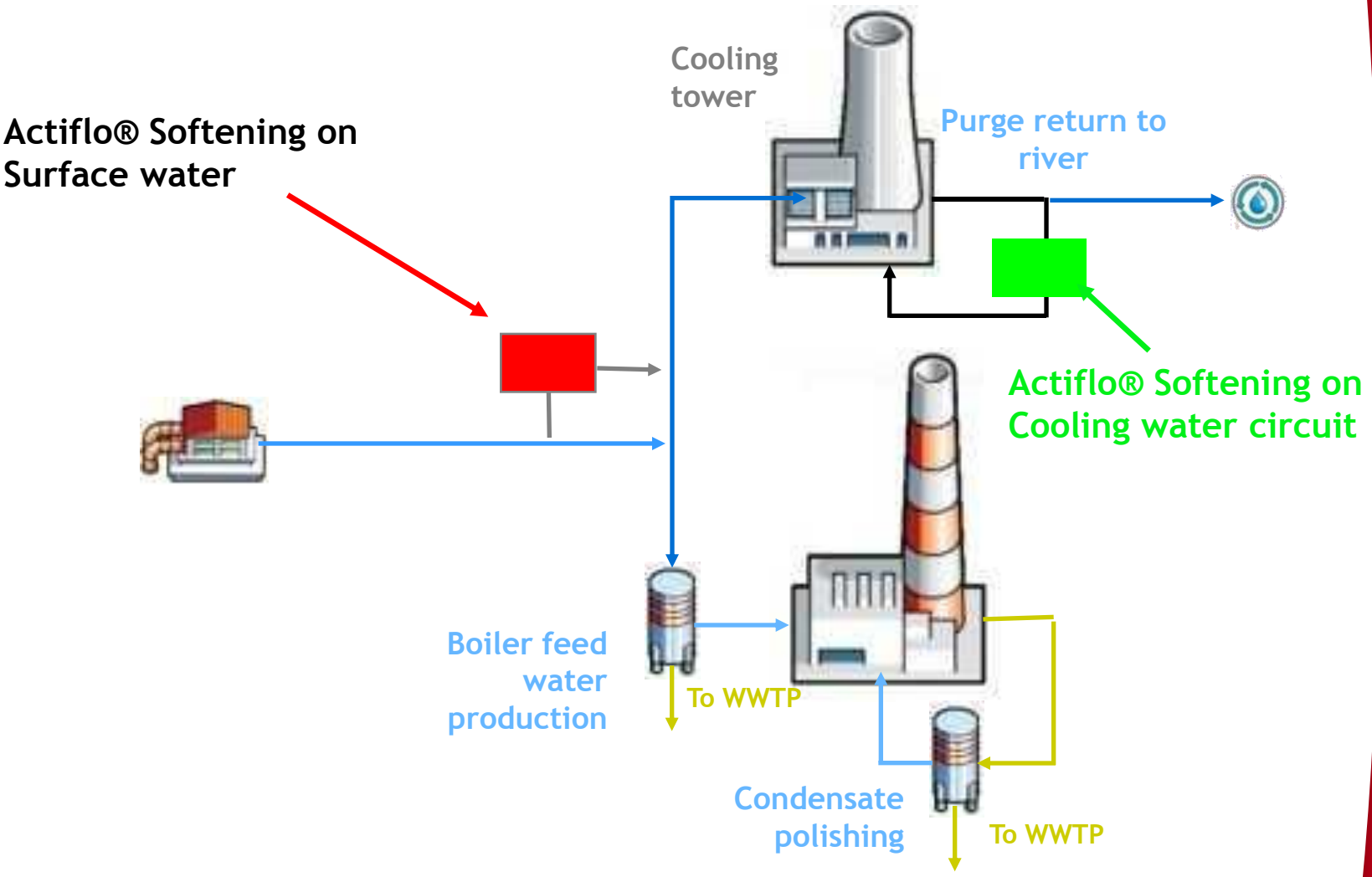


Actiflo Softening Technology

- Sand ballasted clarifier. Small footprint.



Actiflo ® Softening?



Membrane Technologies – Pore Sizes

- Microfiltration: 0.05 - 1.0 µm.
- Ultrafiltration: 0.005 - 0.1 µm.
  (1000 - 500,000 MWCO).
- Nanofiltration: 0.001 – 0.01 µm.
  (200 – 10,000 MWCO).
- Reverse Osmosis: 0.0005 – 0.002 µm.

Single Pass RO Machine

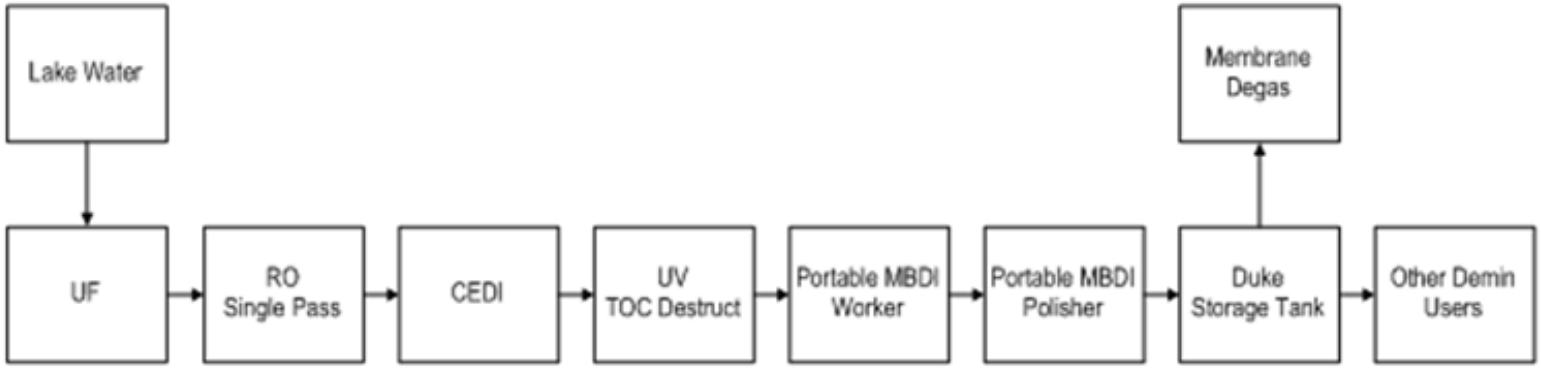
Municipal Wastewater to Power Plant: Cooling Water and Boiler Feedwater

- 650 MW combined cycle power plant
- Water treatment requirements: 5200 GPM Upflow Filter, 1700 GPM UltraFilter, 1200 GPM 2 Pass RO and a 1200 GPM Mixed-Bed DI system along with all supporting equipment
- Concerns: Bacteria, Ammonia, Phosphate, TSS, TOC
- Solutions:
  - Chloramine to minimize THM's, meet TOC limits of 100 ppb, and provide bacteria control.
  - UF and two pass RO

Nuclear Station Makeup Water System

- Lake Water
- 400 gpm with redundancy
- Specification:

  ≤ 0.060 µS, < 2.0 ppb Si, < 10.0 ppb TOC, < 50 ppb dissolved oxygen



Boiler Water Treatment Programs

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Boiler Water Treatment

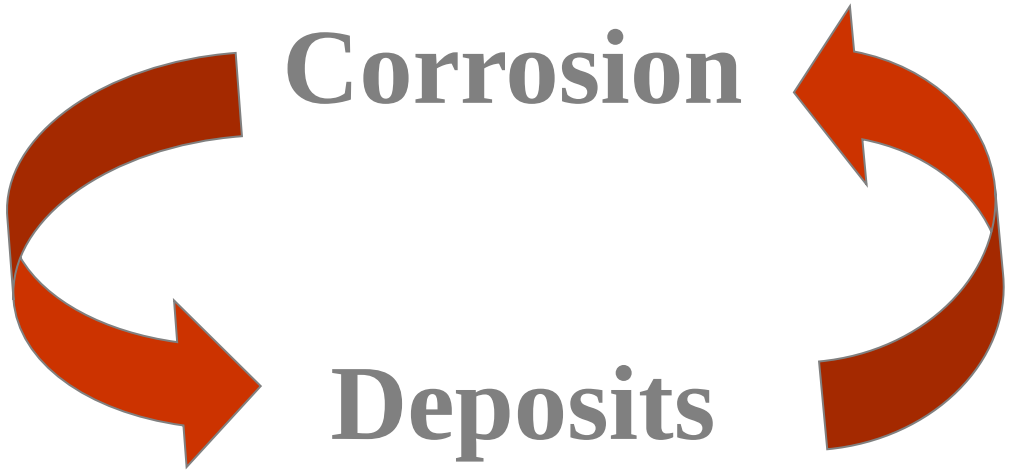
Your Choice

Boiler Chemical Treatments

- Low Pressure Boilers:
  - Chemicals to prevent deposits
  - Oxygen scavengers
  - Condensate corrosion protection
- High Pressure Boilers:
  - Phosphate Alkalinity Control
  - All Volatile Treatment
  - Reducing agents (oxygen scavenger)
  - Oxygenated Treatment for very high purity, high pressure systems

High Pressure Boiler Water Treatment – Prevent Corrosion & Deposits

- Produce Pure Steam to Turbine
- No Deposits
- No Corrosion



Boiler Corrosion

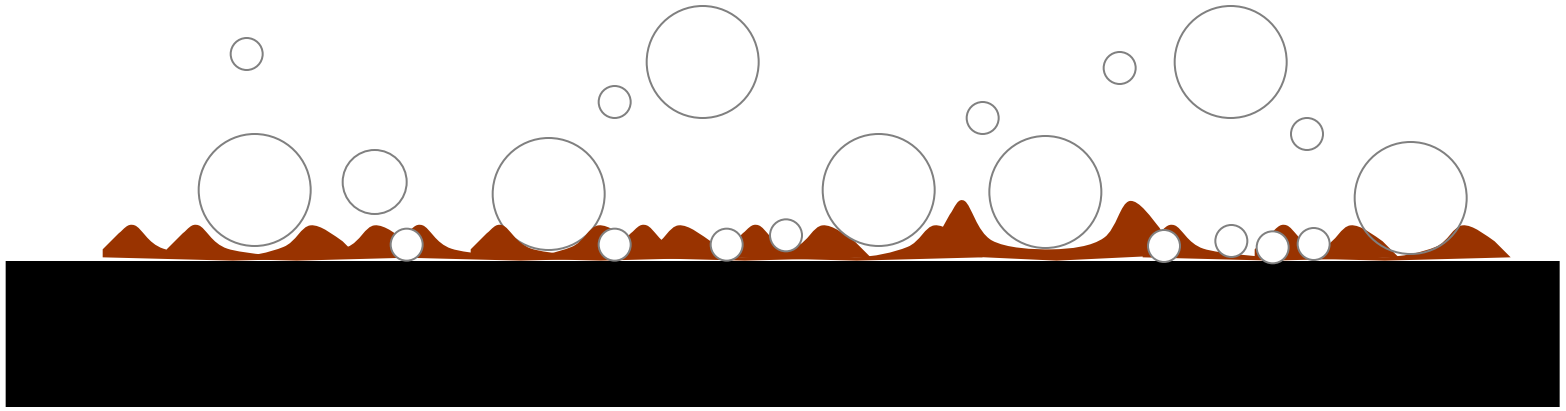
1. Boilers concentrate dissolved solids.
2. Create deposits.
3. Corrosion forms under deposits.
4. Tubes fail.

Rule of Thumb—dirty boilers corrode; clean boilers don’t.

Boiling Modes and Deposits

As steam forms, salts precipitate out of solution. These are typically put back into solution by the boiler water under nucleate boiling conditions.

In high heat areas, deposits accumulate on tube surface.



Effects of Tube Deposits

- Poor Heat Transfer (Overheating)
- Restricted Flow
- Concentration of Corrosive Species & Corrosion

Boiler Metal Passivation - Schikorr Reaction

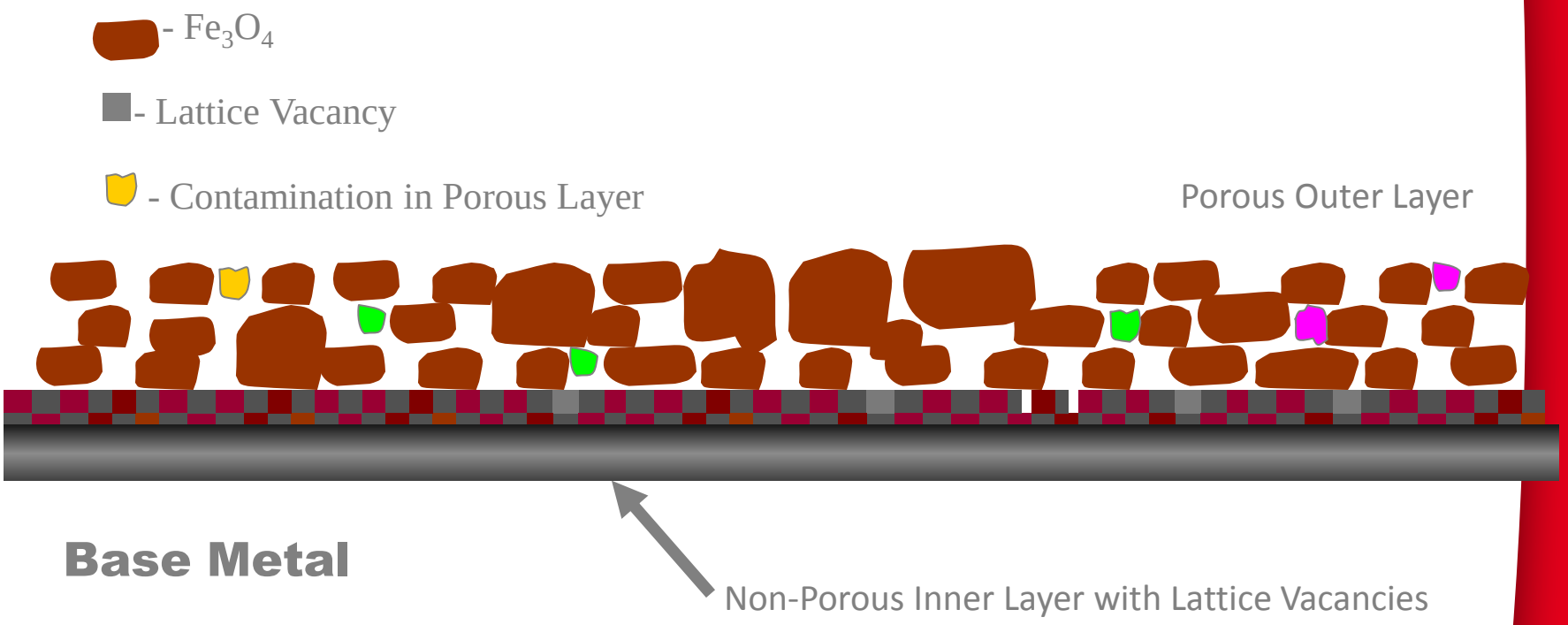
- Metal surface passivation in an operating boiler is a slow controlled corrosion process, taking place on a continuous basis.
- Under design operating conditions, internal boiler corrosion leads to the formation of magnetite on the metal surfaces with the release of hydrogen.
- Well, unhydrated, crystallized magnetite forms a dense layer, providing excellent passivation.

$$Fe + 2H_2O \longleftrightarrow Fe^{+2} + 2OH^- + H_2\uparrow \quad (1)$$

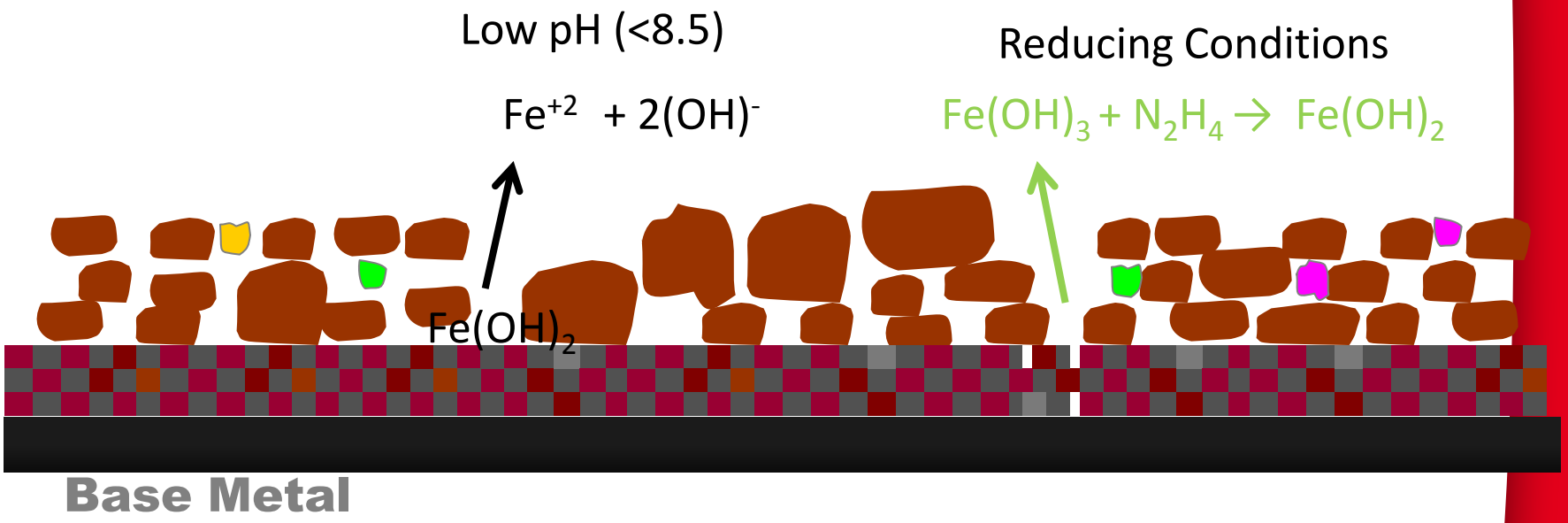
$$Fe^{+2} + 2OH^- \longleftrightarrow Fe(OH)_2\downarrow \quad (2)$$

$$3Fe(OH)_2 \longleftrightarrow Fe_3O_4 + 2H_2O + H_2\uparrow \quad (3)$$

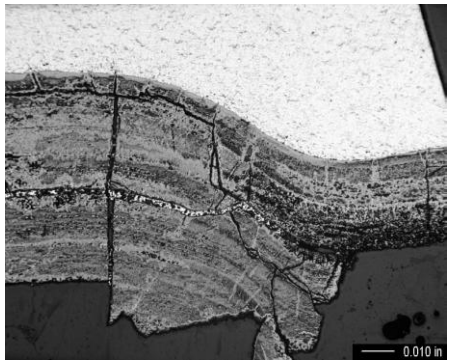
Magnetite Forms in Layers



Magnetite Destabilized

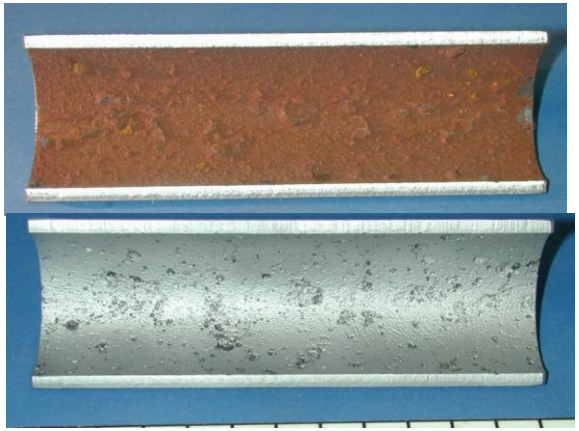


Corrosion Failure Mechanisms

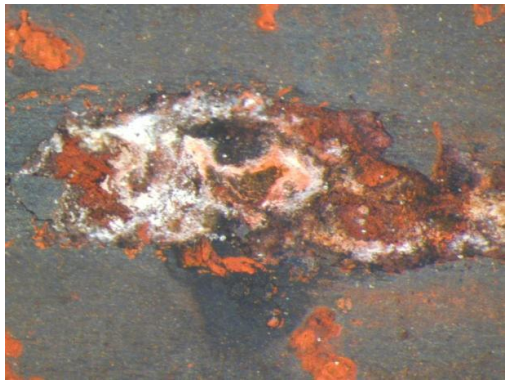


Caustic Gouging

Hydrogen Embrittlement



Oxygen Pitting



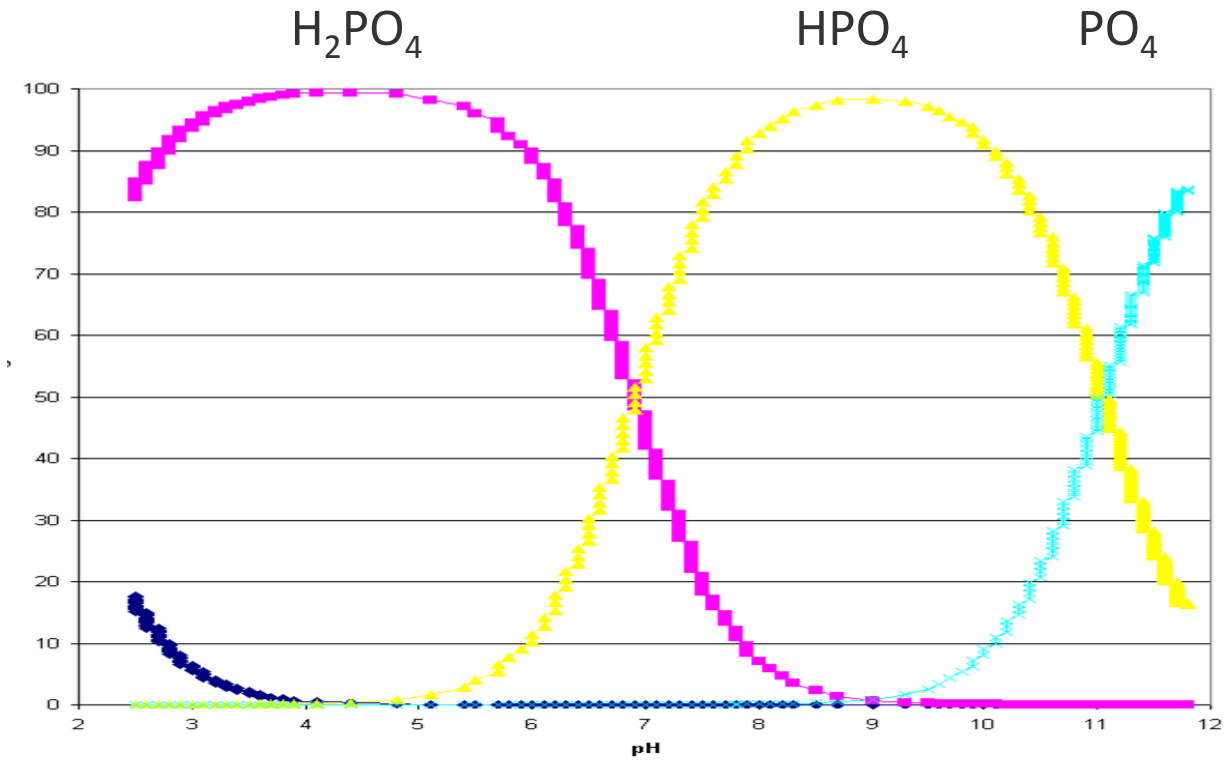
Acid Phosphate Attack

Alkalinity Program Control

- Phosphoric acid (H_3PO_4) is a weak acid.
- It ionizes in water to form three ionized species:
  - Dihydrogen phosphate ($H_2PO_4^-$).
  - Monohydrogen phosphate (HPO_4^{-2}).
  - Orthophosphate (PO_4^{-3}).
- Any style or pressure of drum boiler.
- Solid alkali in the boiler water.
- No restrictions on feedwater metallurgy.
- Protection against <u>small</u> amounts of contamination.

Alkalinity Program Control

- The phosphate forms distribute according to pH and acts to buffer the solution:



Phosphate Treatment Types

- Coordinated Phosphate
  - Keep Na:PO4 ratio between 2.2 – 2.6 using pH and phosphate
  - Feed blends of MSP, DSP, and TSP
  - 2-30 ppm PO_4
- Equilibrium Phosphate
  - Eliminate Hideout
  - Feed only TSP
  - 0.5-2.0 ppm PO_4

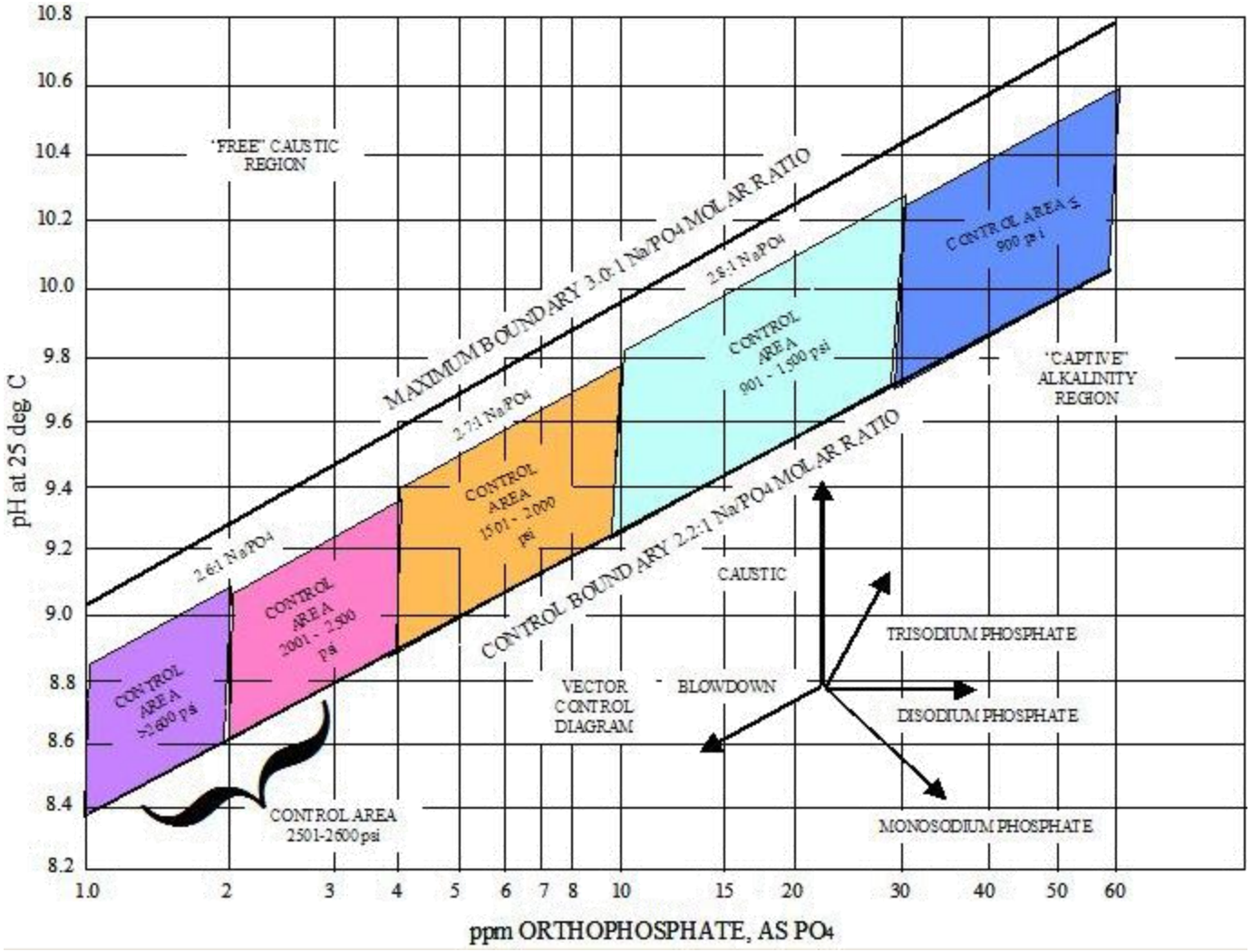
Phosphate Treatment Types

- Phosphate Continuum
  - Feed only TSP
  - Na:PO_4=3 + 1ppm NaOH
  - Choose your own specific limits
  - PC(Low)-very low levels of phosphate

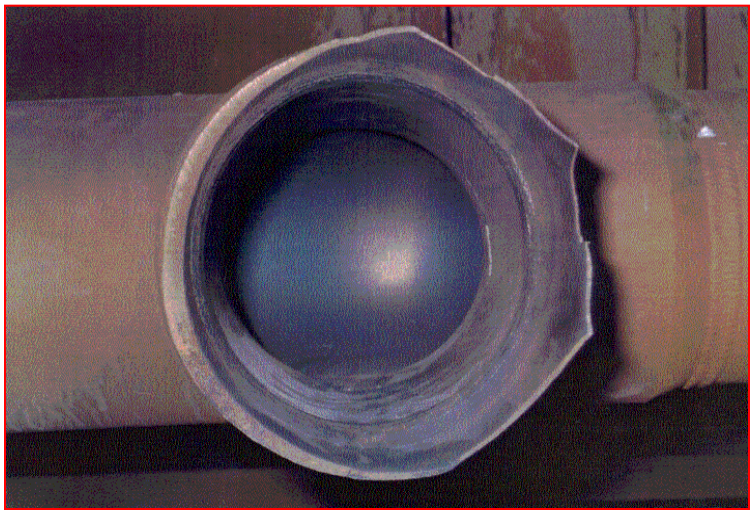
    →High pressure boilers (2400-2600 psig)
  - PC (High)

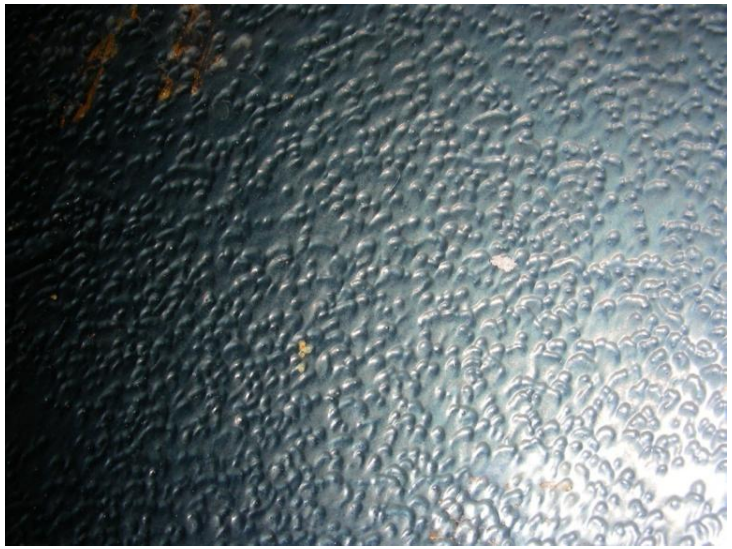
    →Lower pressure boiler (600-1200 psig)

Coordinated Phosphate Control



Flow Accelerated Corrosion





Solutions to FAC

- Elevate feedwater pH to above 9.4 if there are no copper alloys.
- Use a higher alloy (1-2% chromium) such as T-11 or T-22.
- Design to limit U-bends, poor welds, and flow upsets.
- Use smooth tubes.
- Decrease linear flow rates.
- Keep temperatures out of 300°F (149°C) area.
- Keep dissolved oxygen > 5 ppb on an OT program, or oxygen scavenger < 30 ppb on a reducing program.

Steam Purity

- Steam Purity vs Steam Quality
  - Steam purity is the solid, liquid, or vaporous contamination in the steam (ex SiO_2, Na, or Fe)
  - Steam quality is the measurement of moisture in steam
- Steam Purity Guidelines
  - Turbine Manufacturers (PPB)
  - Industry Professional Organizations (ASME, ABMA, etc.) (PPB)
  - Boiler Manufacturers (% or ppm)
  - Operational or process needs

The Most Chemically Sensitive Equipment at the Plant

The Turbine

Cooling Water Treatment

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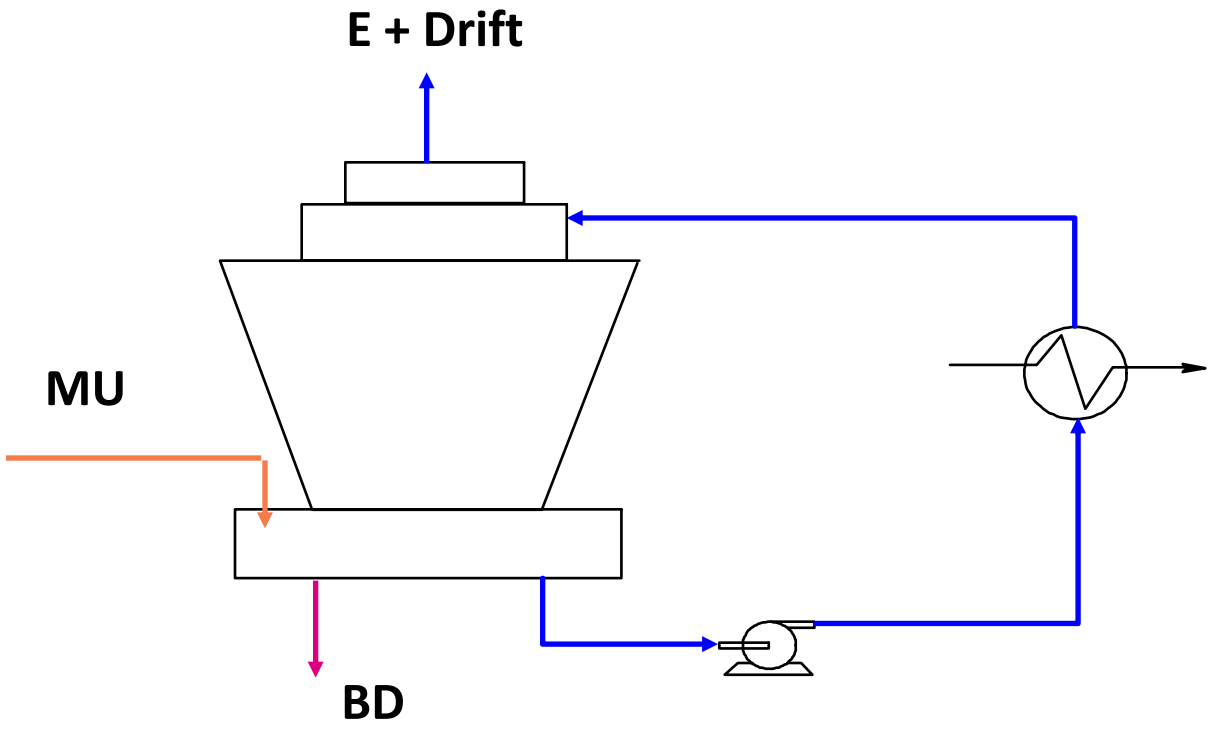
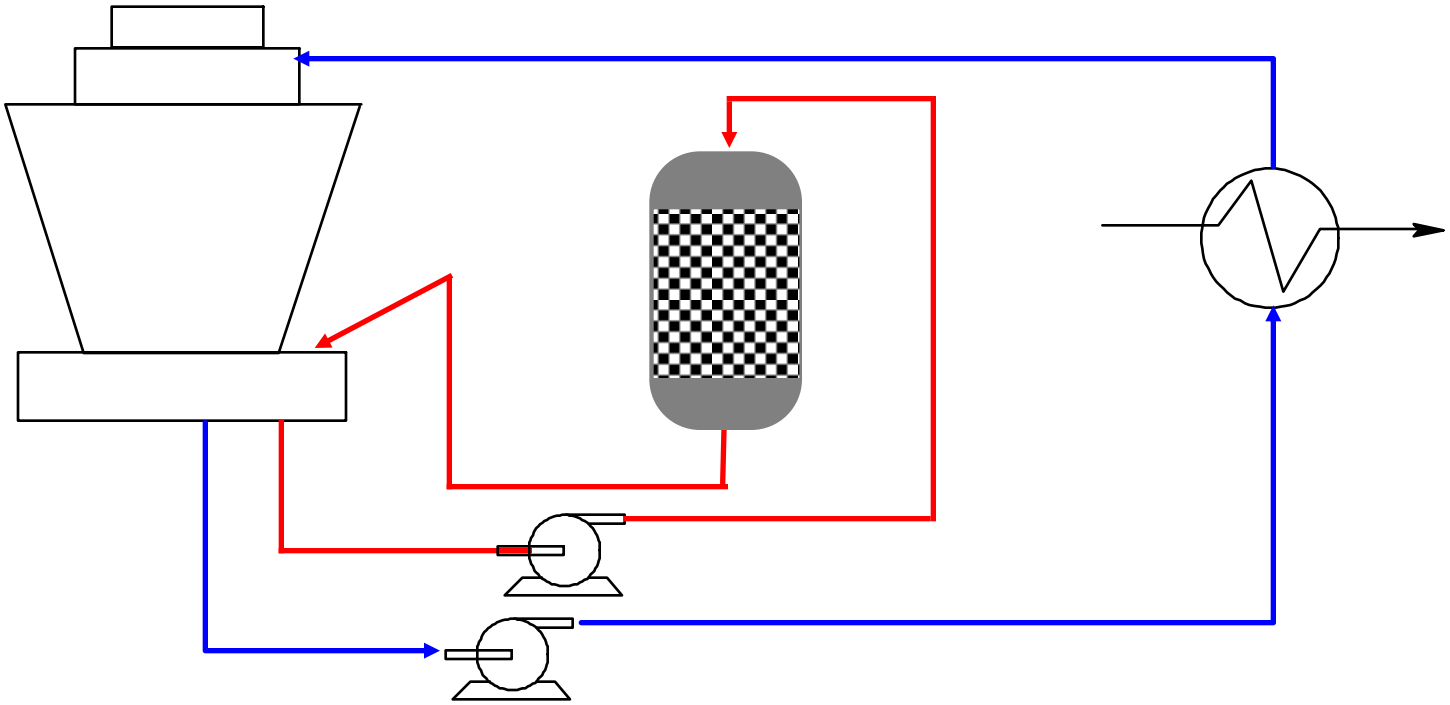
Cooling Tower Mass Balance



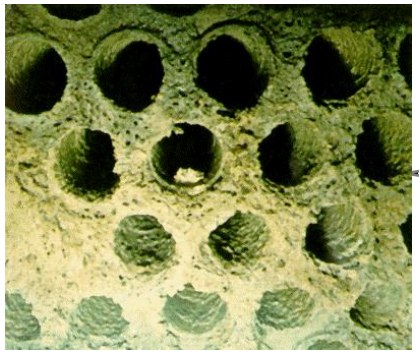
Side stream Filtration

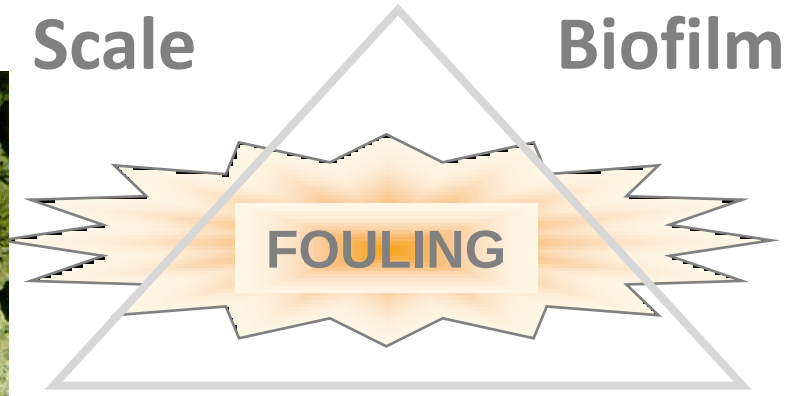
- Side-stream usually 3-5% of recirculation flow
- Best to have separate supply pump, but sometimes use process supply pump.



OPERATION

- Cycles of the cooling water needs to be well controlled
- Three main areas to control





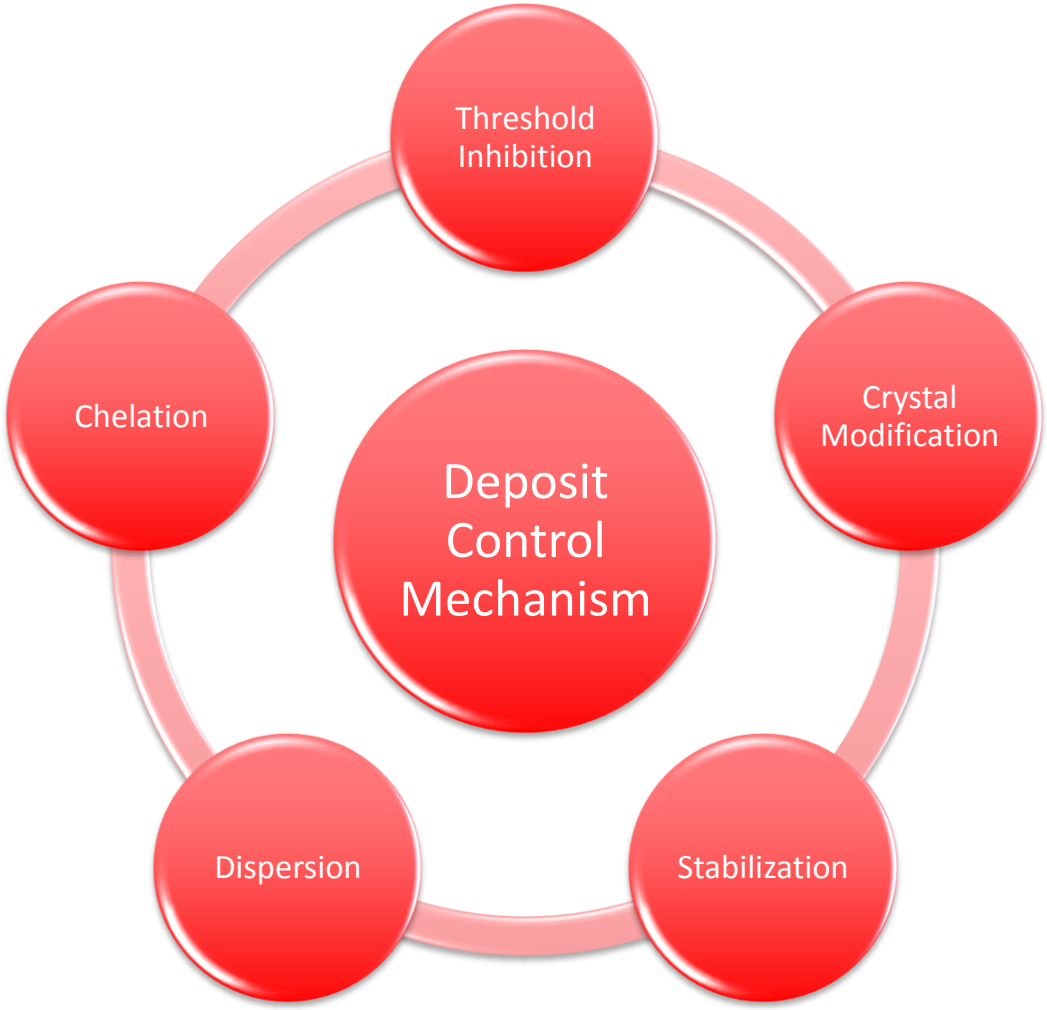
Corrosion

Legionella issue !!!

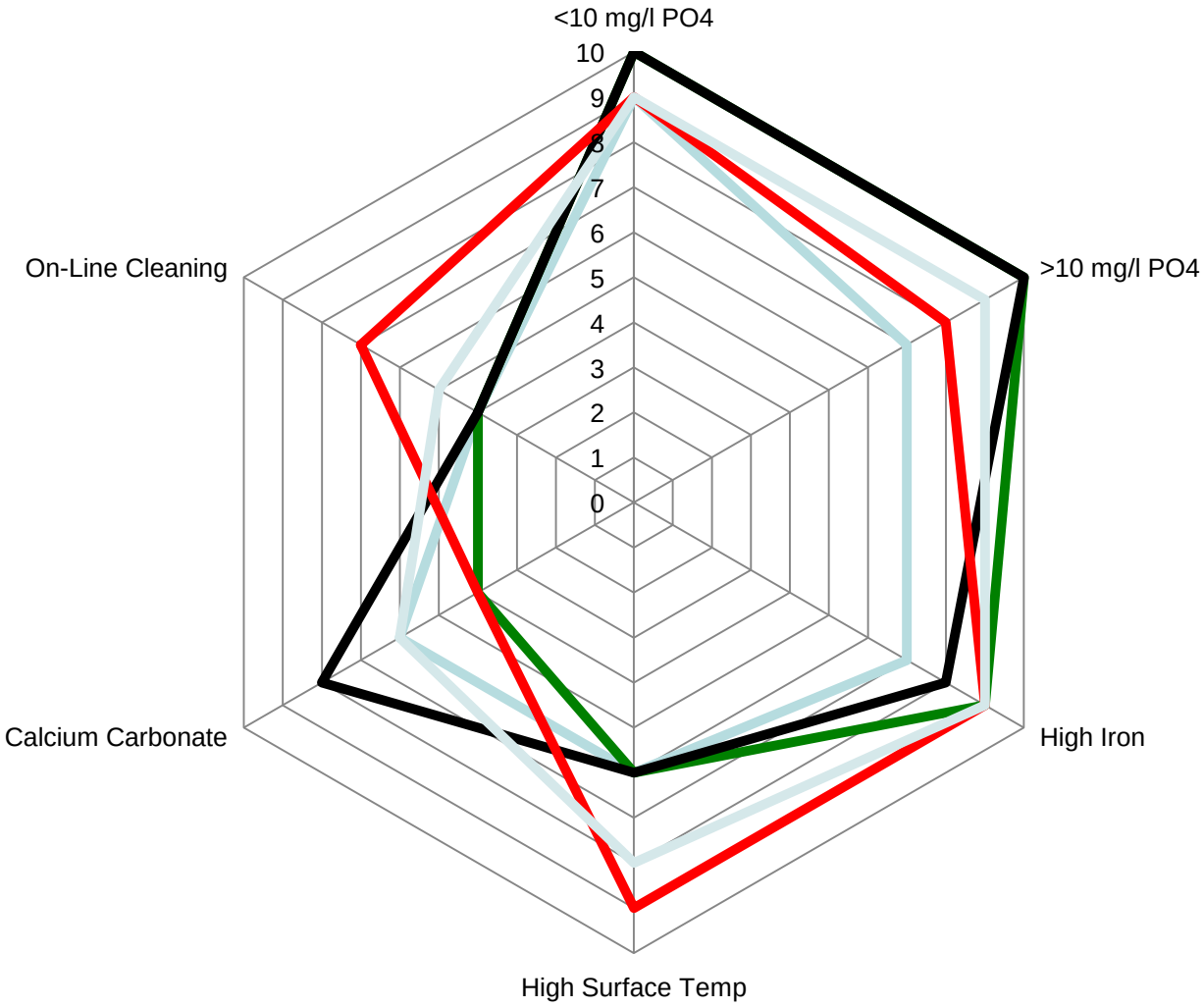
Chemical Treatment Strategy

- Anti-scalants for scale control
- Dispersants for scale, sludge, suspended solids fouling – key component of the chemical treatment program
- Corrosion inhibitors for mild steel, copper most generally, then others such as galvanizing or aluminum
- Organic dispersants and surfactants for system cleanliness and to assist in biocide treatment
- Biocides for MB control

Dispersants Interconnected Functionality



Example of Relative Performance of Different Dispersants



Life Cycle Costs

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Integrated Water Management

A Process Management Focus on the objective integration of chemistry, equipment, service & management for each site's unique circumstances. Solution Options based on both initial- & life-cycle cost.

Total Water Solutions

- **Reduce Overall Cost of Operation & Compliance (OCOC)** through process-oriented technical creativity in the objective development of objective water strategies to provide the optimal solution.

Ultimate Goal: Provide A Competitive Advantage

- **Combine chemicals, labor, maintenance, technical service**, **engineered systems & program management** to integrate all components as the site Water Manager.

- The result: **A Process Management Focus** on the objective application of technology based on both initial & life-cycle expense. This provides the most cost-effective integration of chemistry, equipment, service & management for each site's unique circumstances.

Competitive Perspective – Capability Analysis of Key Suppliers
-Frost & Sullivan Analysis-

	Boiler Water Make up Plant	Condensate Polishing	Zero Liquid Discharge System	O/M	Services	Overall Project Mgmt	
Veolia Water	●	●	●	◔	◑	◔	Complete solution provider with a global presence
BGR	●	●	○	○	◑	◑	One of the fastest growing companies in India with a comprehensive capability of supply steam turbines as well as water & wastewater treatment in India.
GE Water	●	●	●	◔	◑	◔	Specialist in advanced water & wastewater treatment solutions for the power sector. Witnessing success with water selling related projects in North America.
Aquatech International Corp	●	◔	●	◑	◑	◔	Market leader in the ZLD segment . Recently started its office in Netherlands as part of its global expansion plans.
Metito	●	○	○	○	◑	◑	One the established and leading players in the power plant water market of the Middle East.
Driplex Water Engineering Ltd	●	●	○	◑	◑	◔	Market leader in power plants water market in India. Established a strong client base that includes major power companies such as NTPC, BHEL etc
Asia Water Technology	●	●	○	○	◑	◑	Services power plants in China through it subsidiary Wuhan Kaidi Water Services Co Ltd One of the 3 license owners to service water needs of nuclear power plants in China
Ovivowater	●	●	●	◑	◑	◑	Emerged from the recent merger of Eimco and Christ Water Technology
Hager + Elsasser	●	◔	○	○	◑	◑	Regional player restricted to Europe & certain parts of Russia.. Expertise in high purity water segment

Key: Full ● Majority ◔ Partly ◑ None ○