Changing Requirements for Cooling Tower Water Treatment

McIlvane Webinar
Power Plant Cooling Towers and Cooling Water Issues
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The Current Scenario

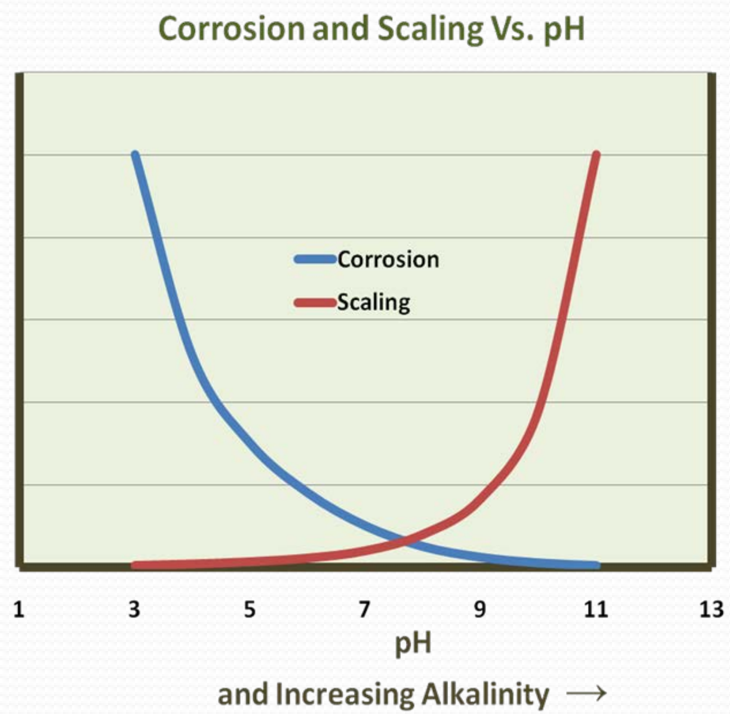
- We are seeing a continual stream of combined-cycle power plant RFPs.
- Not one has called for once-through cooling, in large measure due to pending 316a and 316b regulations.
- The two primary alternatives consistently required are:
  - Wet cooling towers (the focus of this presentation)
  - Air-cooled condensers

The Need for Continued Cooling Water Training

- Many new personnel will need to learn about cooling water technical issues, due to:
  - Increasing restrictions on cooling water discharge
    - Quality (heavy metals, phosphates, TDS and others)
    - Sometimes quantity
    - Temperature
  - Retirements of many experienced personnel, particularly the “Baby Boomers”

Alkaline Treatment Has Been the Preferred Choice

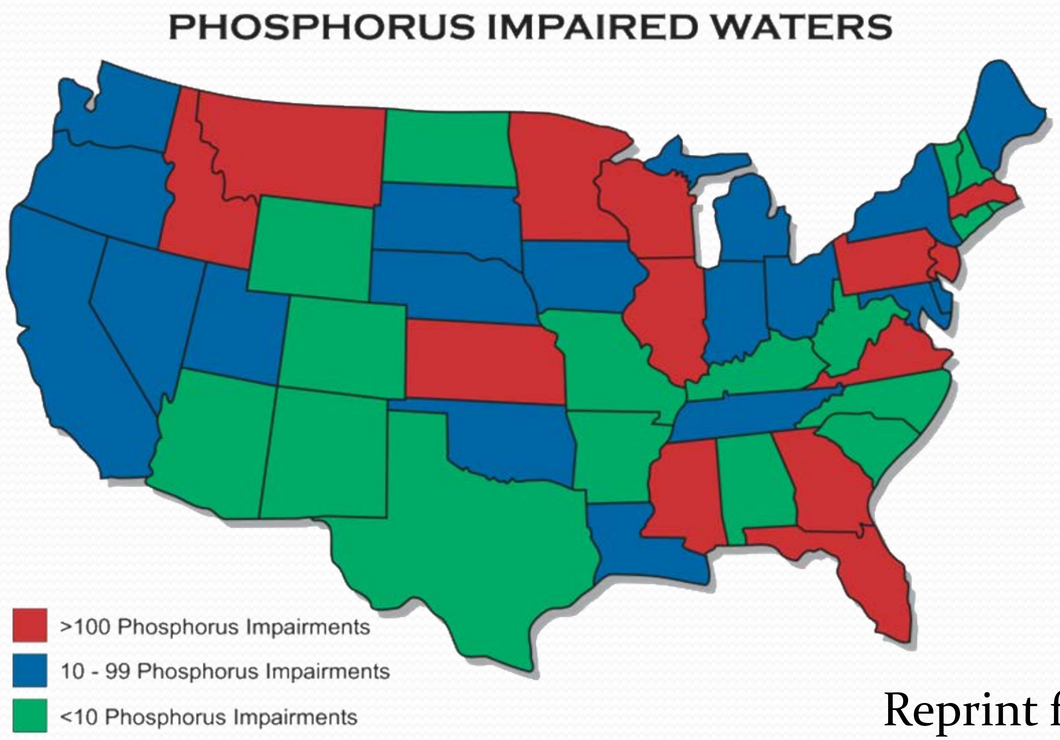
- Alkaline pH minimizes general corrosion at the expense of greater scaling tendency
- Some ortho-phosphate to complex calcium and generate a cathodic protection product $[Ca_3(PO_4)_2]\downarrow$
- Perhaps one ppm of zinc to add protection at cathodic sites $[(Zn(OH)_2\downarrow]$
- Organic phosphonates to control $CaCO_3$ scale at higher pH
- A small polymer dosage to help control calcium phosphate scaling



Source: Ray Post - ChemTreat

New Developments

- Phosphorous and zinc compounds have been the backbone of corrosion and scale control in the post-chromate years
- For many cooling systems, new standards will limit the use of phosphorous and zinc, especially for larger systems that discharge to public waterways.
- Non-phosphorous options are emerging for cooling water treatment.



Reprint from Ref. 1.

Non-Phosphorous Scale Inhibition

- Key non-phosphorous deposit control agents include:
  - Polyacrylates and enhanced polyacrylates
  - Maleates and enhanced maleates
    - COOH is the functional group
  - Aspartates (acrylamides)
  - Co-, ter-, and quad-polymers
    - Functional groups include COOH, SO_4, acrylamides

- Combination of actives provides the best performance

Don’t Forget About Microbiological Fouling

- Fundamental treatment principles to prevent microbiological fouling have been known for many years, but problems consistently remain.
- Cooling systems are an **ideal habitat** for microorganisms.
- Microorganisms exhibit **log growth** and will foul a system more quickly than any other contaminant.

Biofouling Organisms

- Algae
  - Require sunlight for growth (tower deck)
  - Convert bicarbonate into organic carbon
    - Food for bacteria
  - Food for protozoa and “higher life forms”
- Fungi
  - Break down complex organics
    - Tower wood fibers
  - Molds and Yeasts
- Bacteria
  - The most diverse group
  - Heterotrophic
  - Facultative
  - Anaerobic
  - Autotrophic
- Macrofouling Organisms
  - Zebra mussels, Asiatic clams

Microbiological Control

- Gaseous chlorine use has declined greatly due to safety concerns.
- Bleach begins to lose effectiveness quickly as pH rises above 7.5.
- Very common has been feed of bleach and sodium bromide to generate bromine, which is more effective at pH 8 to 8.5.

Microbiological Control – ***Chlorine Dioxide***

- Chlorine dioxide (ClO_2) is an alternative, but has often been too expensive and must be generated on-site.
- A lower cost production option based on sodium chlor<u>a</u>te is gaining popularity. The chemistry is:
  - $NaClO_3 + \frac{1}{2} H_2O_2 + \frac{1}{2} H_2SO_4 \rightarrow ClO_2 + \frac{1}{2} Na_2SO_4 + \frac{1}{2} O_2 + H_2O$
  - Sodium chlorate and hydrogen peroxide are supplied as a stable blend
- Chlorine dioxide advantages
  - Not influenced by pH
  - Does not form halogenated organics
  - Does not form weak chloramines
  - Fast acting

Microbiological Control - *Monochloramine*

- Monochloramine (NH_2Cl) is also gaining some notoriety.
  - Reaction of gaseous chlorine or bleach with ammonia or ammonium hydroxide.
- Monochloramine is not as potent as free chlorine, but
  - Longevity is greater
  - Less corrosive than free chlorine
  - Reportedly better at penetrating biofilms
- Chloramination is already commonly used in municipal potable water systems to limit THM production

Microbiological Control – *Non-Oxidizers*

- Non-oxidizing biocides are often a very viable technology to supplement oxidizers.
  - DBNPA
  - Isothiazolin
  - Glutaraldehyde
  - Quaternary amines
- Effectiveness is more specific to the type of organism
- Longer lasting than oxidizing biocides
  - Layup, closed loops, dead legs
- Much less corrosive than oxidizers
- More effective at penetrating biofilms
- More effective against macrofouling

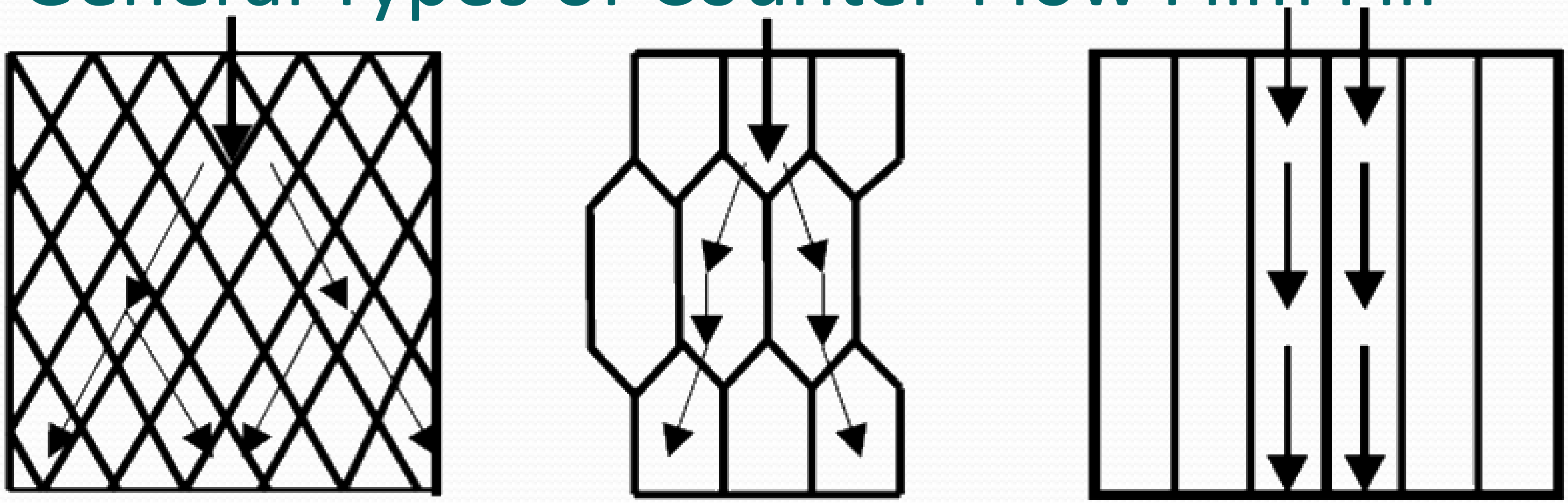
Cooling Tower Fill Selection

- Cooling tower fill should maximize heat transfer but not at the expense of severe fouling.
- Selection is extremely dependent upon the quality of makeup water.
- More frequently, reclaimed water is being utilized for plant makeup.

Factors That Influence Fill Performance

- Flow path configuration (cross-flutes, offset-flutes, vertical-flutes)
- Flute size (specific surface area)
- Surface micro-structure

General Types of Counter-Flow Film Fill



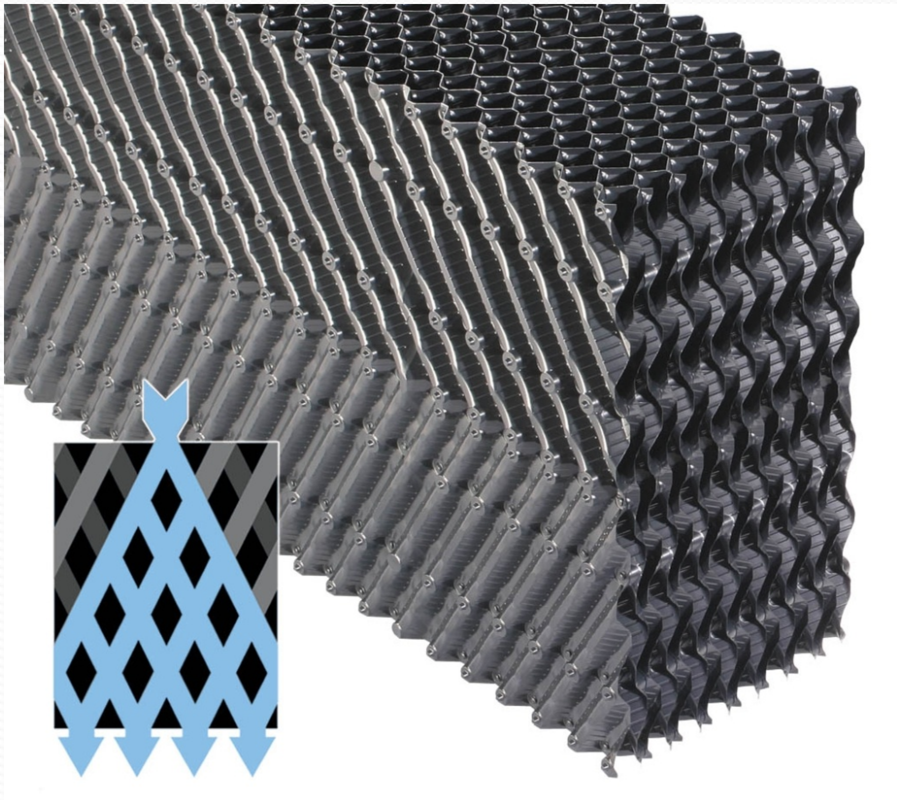
Cross-Flute Design | Offset-Flute Design | Vertical-Flute Design

Decreasing tendency to clog →

← ***Increasing performance***

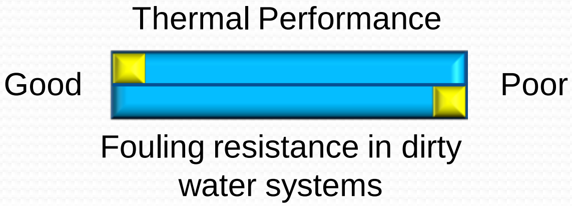
Source: Rich Aull, Brentwood Industries

High-Efficiency Film Fill



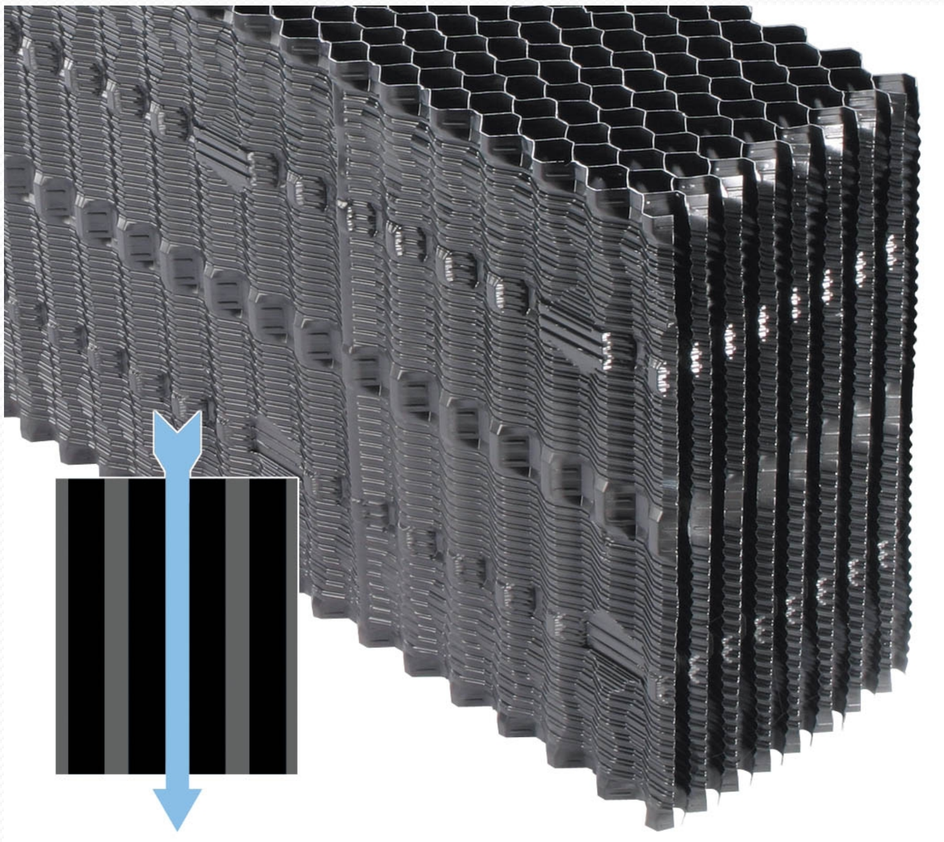
Cross Flute (CF)

- Large specific surface area
- High performance
- Poor anti-fouling characteristics in fouling waters



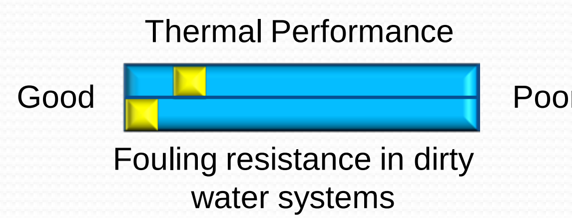
Source: Rich Aull, Brentwood Industries.

Anti-Fouling Film Fill



Vertical Flute (VF)

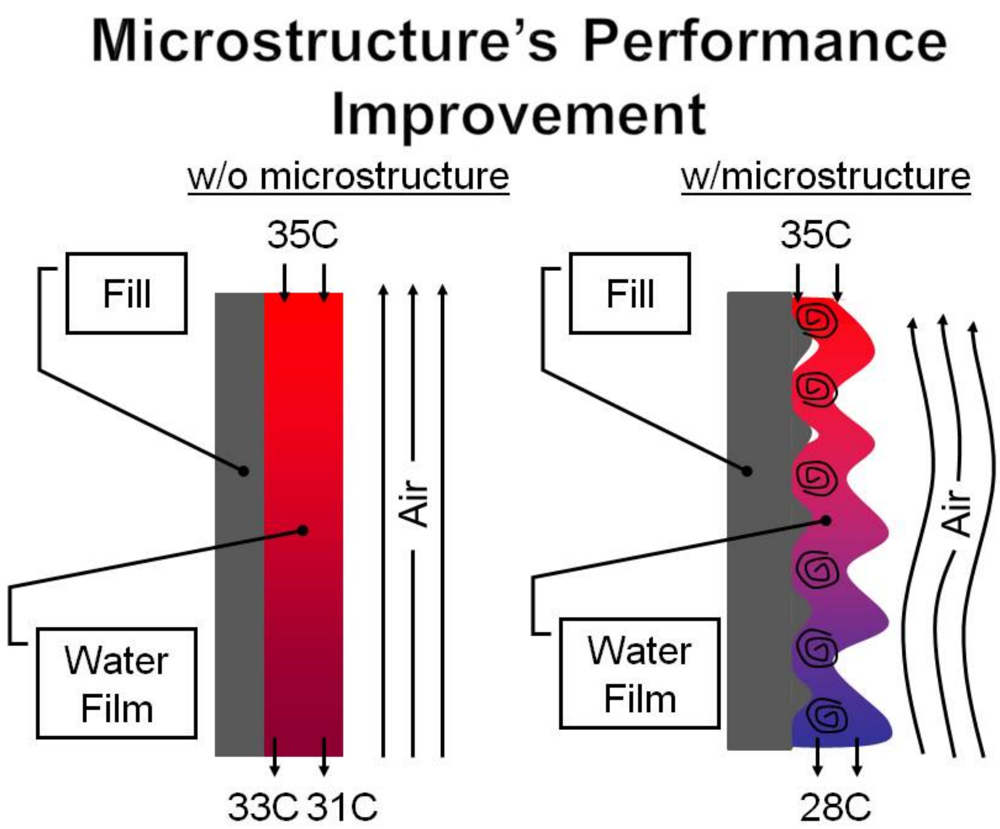
- Lower specific surface area
- Moderate performance
- Excellent anti-fouling characteristics



Source: Rich Aull, Brentwood Industries. An expanded discussion may be found in Ref. 1.

Film Fill Surface Structure

Surface structure enhances air/water contact



Source: Rich Aull, Brentwood Industries

Cooling Tower Discharge

- For decades, power plant water discharge has been covered under the National Pollutant Discharge Elimination System (NPDES).
- In many cases, the following four parameters were primarily regulated.
  - Total suspended solids (TSS)
  - pH
  - Oil and grease (O&G)
  - Residual oxidizer (chlorine, bromine, etc.) at the cooling water outfall

Cooling Tower Discharge

- NPDES guidelines are changing
  - The USEPA is preparing to issue new guidelines this year.
  - Some states have already implemented new control guidelines.
- Additional parameters on some lists include:
  - Total dissolved solids (TDS)
  - Sulfate
  - Copper
  - Zinc
  - Ammonia
  - Phosphate
- We are also seeing discharge quantity restrictions in some areas such as California.

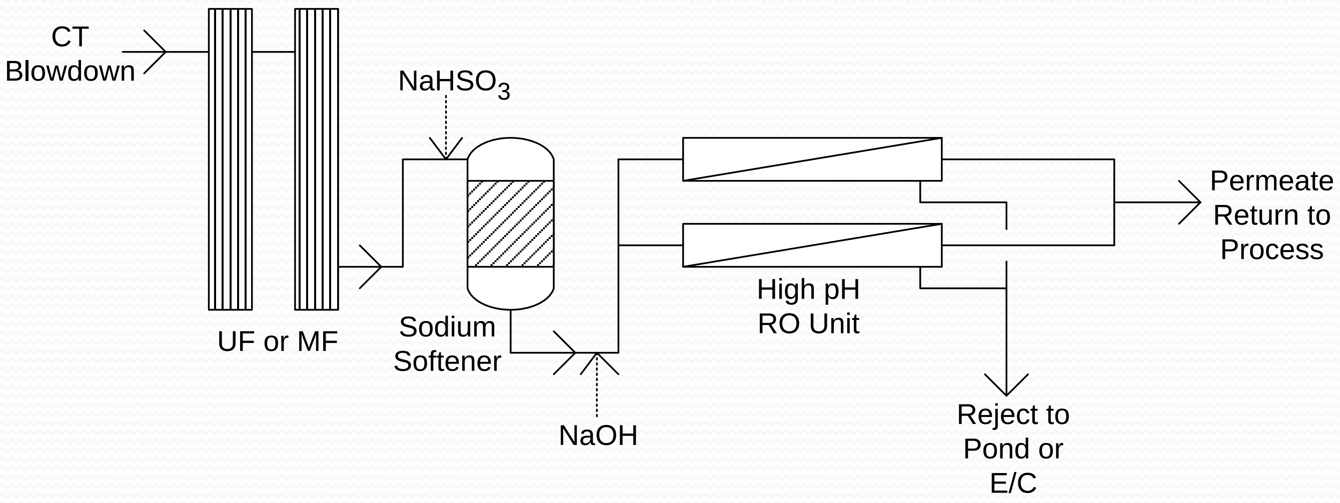
Cooling Tower Discharge

- Control of discharge chemistry can put plant personnel between the proverbial "rock and a hard place," particularly if the makeup is of poor quality or the cooling tower is required to run at high cycles to conserve water. Some examples of troublesome makeup include:
  - Treated municipal wastewater
  - High dissolved solids well water
- **Air pollution permits may limit TDS in the tower due to atmospheric particulate formation.**

Wastewater Treatment

- Many plants are being faced with discharge control, and the dreaded phrase “zero liquid discharge” is being heard more often.
- An emerging wastewater reduction technology utilizes membranes and softening to lower volume.
  - HERO® (High Efficiency Reverse Osmosis), licensed by Aquatech and GE.
  - OPUS®, licensed by Veolia.

Core Design of RO-Based WWT Systems



Core Design of RO-Based WWT Systems

- UF or MF for particulate removal
- Sodium bisulfite ($NaHSO_3$) feed to remove oxidizing biocides
- Sodium softening to remove calcium and magnesium hardness
- Caustic injection to keep silica in a soluble form
- RO to recover ~ 90 percent of the water

Concerns

- The process is not foolproof. Recent issues we have directly encountered include:
  - Some standard cooling water chemicals may foul the UF membranes.
    - The membrane manufacturer and type can greatly influence fouling.
    - Coagulants may not be effective at converting the chemicals into filterable flocs.
  - Low quality backwash water can cause scaling of UF membranes.
  - Clarification of the influent stream may be required.

Concerns

- Even with 90 percent water recovery, a liquid stream still remains. Possible disposal solutions include:
  - Evaporation ponds
  - Deep-well injection
  - Thermal evaporation/crystallization
  - Truck the liquid off-site to a waste disposal company.

Summary

- Cooling towers are an extremely well-understood technology for removing heat.
  - They can produce lower circulating water temps than ACCs during hot weather.
- Chemistry control within the tower itself and with regard to blowdown chemistry is becoming much more complex due to changing regulations.
- Even at relatively low cycles of concentration, significantly more water is lost to evaporation than blowdown.
  - Impacts water usage.
  - Airborne solids can be of concern.

Reference

1. Buecker, B., Aull, R., P.E., and R. Post, P.E., "Chemical Treatment and Fill Selection Methods to Minimize Scaling/Fouling in Cooling Towers"; 2011 International Water Conference, November 13-17, 2011, Orlando, Florida.

Also, the half-day pre-conference seminar at this year's Electric Utility Chemistry Workshop will be on cooling water, where Ray Post of ChemTreat will assist me. The conference will be held June 11-13 in Champaign, Illinois, and registration is still open. Information can be found at, **www.conferences.illinois.edu/eucw**

Thank you!

I always enjoy discussing power plant issues.
Please feel free to contact me at the following:

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