Air Cooled Condenser Commissioning ACC User's Conference September, 2011

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Problem Statement

- Contamination from new Air Cooled Condensers will have a significant impact on new plant operations during commissioning.
- ACCs contamination includes particulate material, silica and salts that contribute to cation conductivity.
- The carbon steel surface of Air Cooled Condensers is many times that of surface condensers fabricated with stainless or titanium tubes.
- Weld slag, residual flux and the oxidation products of carbon steel are present in greater quantities in an ACC.

Solution Statement

- Particulate contamination is best removed by vigorous mechanical flushing.
- Silica and salts that contribute to cation conductivity can be removed by performing a chemically assisted steam rinse of the ACC during initial operations.
- It is also important to form a protective passive metal oxide coating on carbon steel surfaces of a new ACC.

Particulate Contamination
Mill Scale

- During fabrication of carbon steel plates, pipe and tubing, the metal is heated to 1,150 ^{0}C (2,100 ^{0}F).
- At this temperature, oxygen diffuses into the metal surface and occupies locations in the steel crystalline structure.
- This process is similar to heat treatments that diffuse carbon into the metal surfaces to case harden steel. Like high carbon steel, mill scale is hard and brittle. It is effectively an oxygen alloy of steel

Particulate Contamination
Loose Mill Scale

- At the steel mill, mill scale is tightly adhered to the base metal surface. It is very difficult to remove.
- The bimetallic junction exists between the thin layer of mill scale and the underlying base metal.
- Atmospheric corrosion will preferentially oxidize base metal under the mill scale.
- The atmospheric corrosion product formed beneath mill scale will weaken the bond between the mill scale and base metal.

Particulate Contamination

- Mill scale not undercut by atmospheric corrosion has no solubility in steam or steam condensate. It will remain tightly adhered to the steel surface.
- Loose, thin flakes of mill scale are easily transported by both steam and condensate.
- Loose mill scale, slag and debris left by the assembly of the ACC will rapidly foul condensate pump strainers.
- Small particulate matter that is not removed by the condensate pump strainers may also foul BFW pump strainers and the trim of control valves.

Mechanical Flushing

- BES&T has experience in the commissioning of nearly 20 Air Cooled Condensers.
- Past experience has shown a high volume flush of tubes and the condensate collection system is adequate to remove mill scale, slag and construction debris.
- This flush is best performed within the two weeks prior to the first steam admission to the condenser.
- The effectiveness of a high volume mechanical flush is monitored by use of Millipore filters and measurement of flush water conductivity.

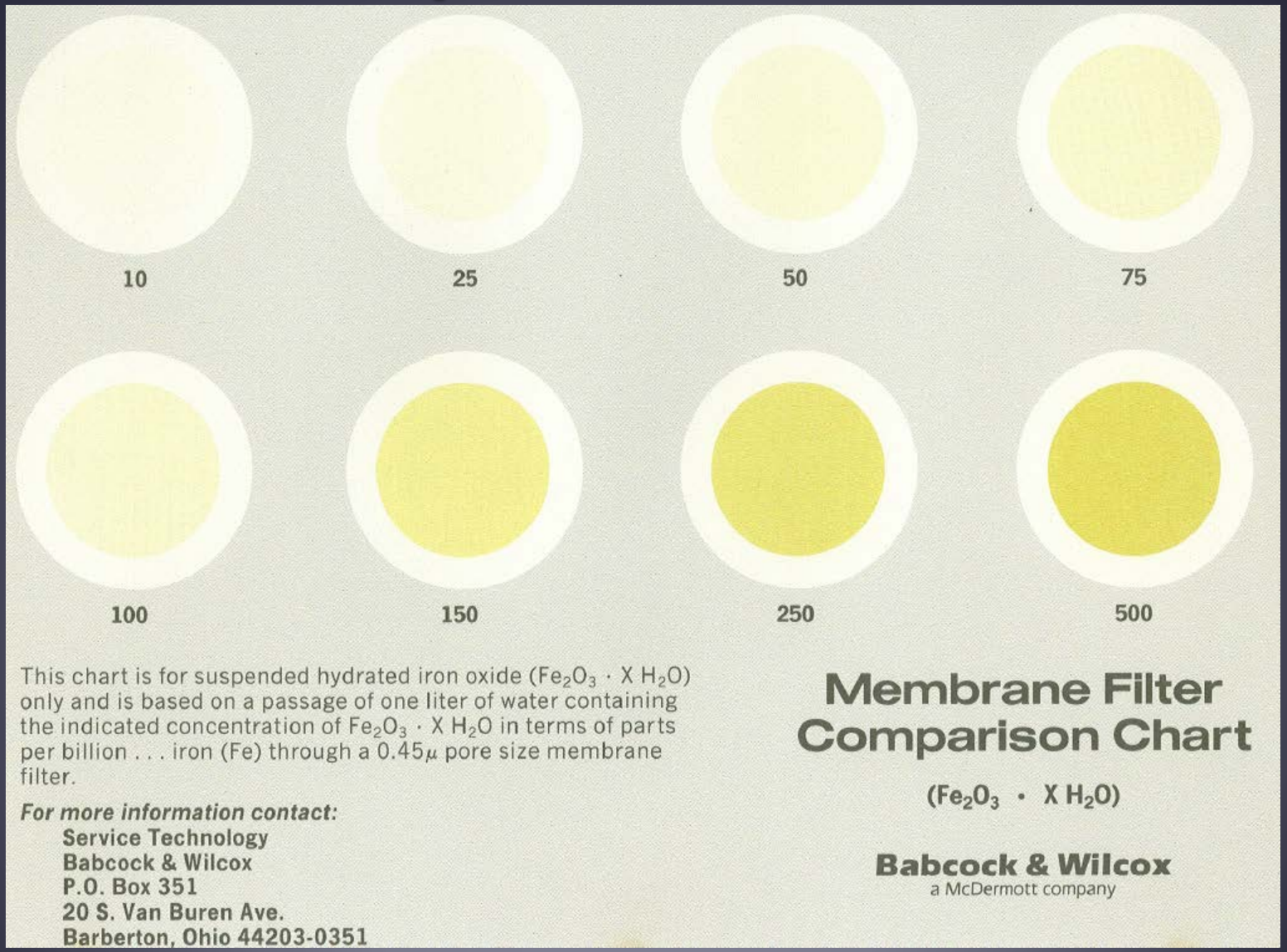
Millipore Filtration

- Millipore filters are a standard method for measurement of total suspended solids.

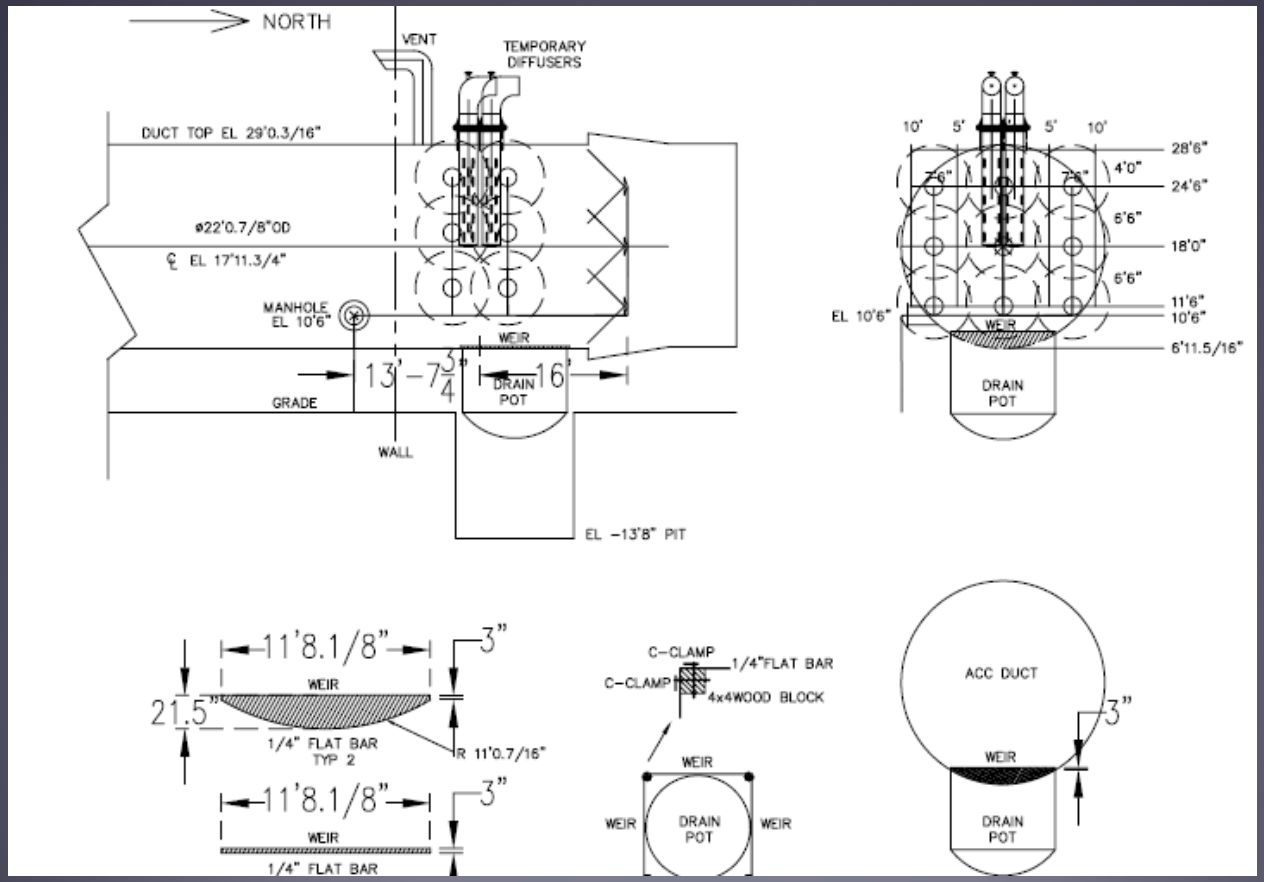
Initial Millipore
650 µS/cm

Final Millipore
10 µS/cm

Suspended Solids



ACC Design for Commissioning



ACC Design for Commissioning

Silica

- Steam cycle silica concentrations must be reduced to acceptable levels prior to steam admission to the steam turbine.
- Silica is a significant component of construction site dust.
- Silica is also an important constituent of steel, weld filler metals and weld fluxes.

Silica Sources

- Silica Gel is often used as a desiccant to limit corrosion in ACC components.

It is important to insure that all silica gel bags are removed from the ACC headers, deaerator and condensate collection tank.

Vapor Phase Inhibitors

- In the last 20 years, use of Vapor Phase Inhibitors (VPI) has become common. VPIs offer excellent protection to carbon steel surfaces against excessive atmospheric corrosion.
- VPIs are water soluble and are easily flushed from the ACC during the initial stages of the steam flush.
- Based on BES&T experience, the use of Vapor Phase Inhibitors is preferable to the use of silica gel bags to mitigate atmospheric corrosion.

Additional Silica Sources

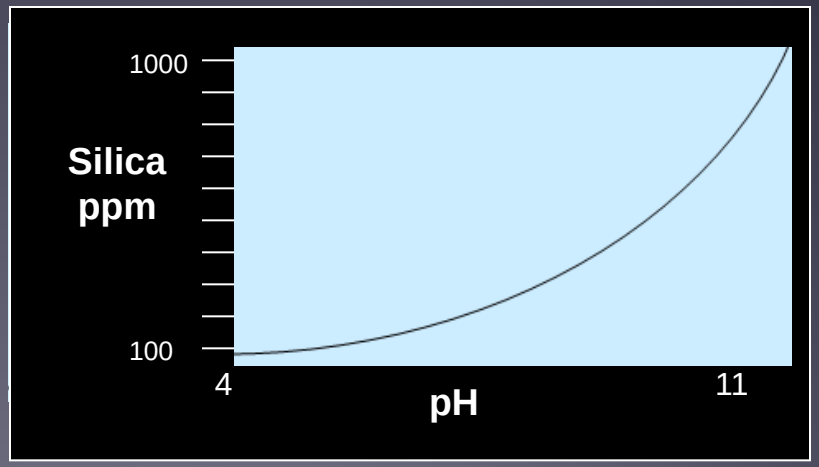
- Silica is added to steel at the steel mill as a fluxing agent to remove oxygen from the steel.
- Higher concentrations of silica are often formulated into weld consumables and weld flux for the purpose of scavenging oxygen from weld metal.
- Residual weld slag and flux left from ACC fabrication is a significant source of silica in condensate returned from an ACC during commissioning.

Silica Solubility

- The solubility of silica in steam and condensate is limited. The rate at which an ACC can be made ready for normal service is dependent on the rate at which silica can be removed from the steam cycle.
- Silicon dioxide hydrates in the presence of steam and condensate to form siliceous acid ($H_2 SiO_3$).
- The solubility of siliceous acid is a function of both temperature and pH.

Silica Solubility

- Silica solubility is increased at higher pH



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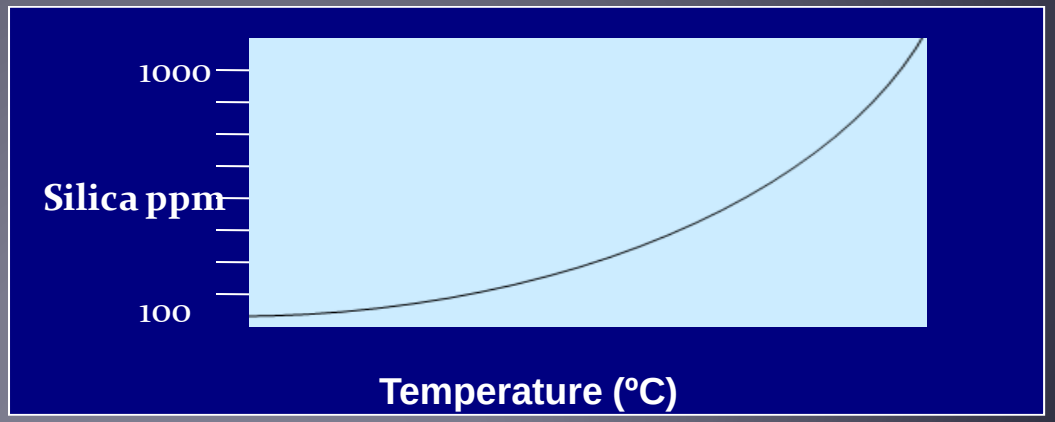


Silica Carryover from Drums

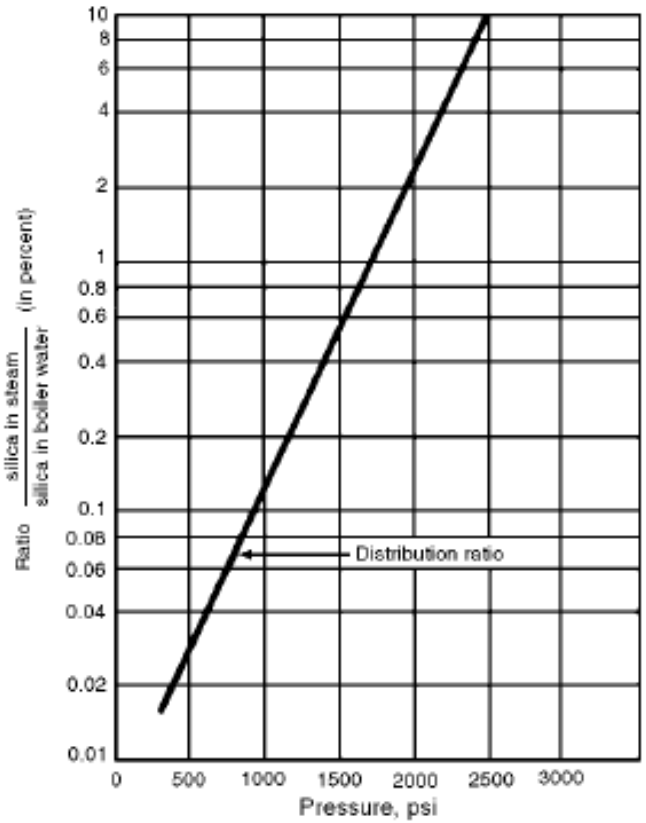


Figure 1 — *Silica distribution ratio*

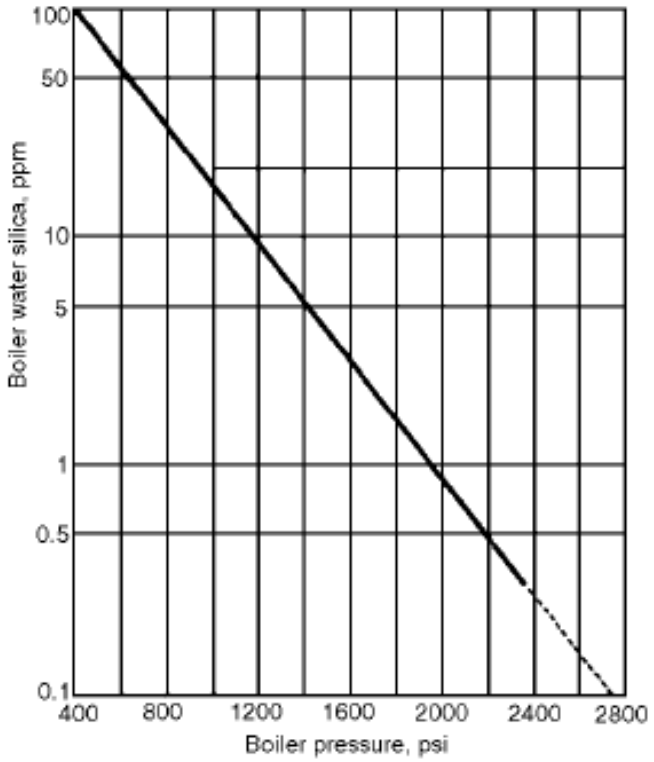
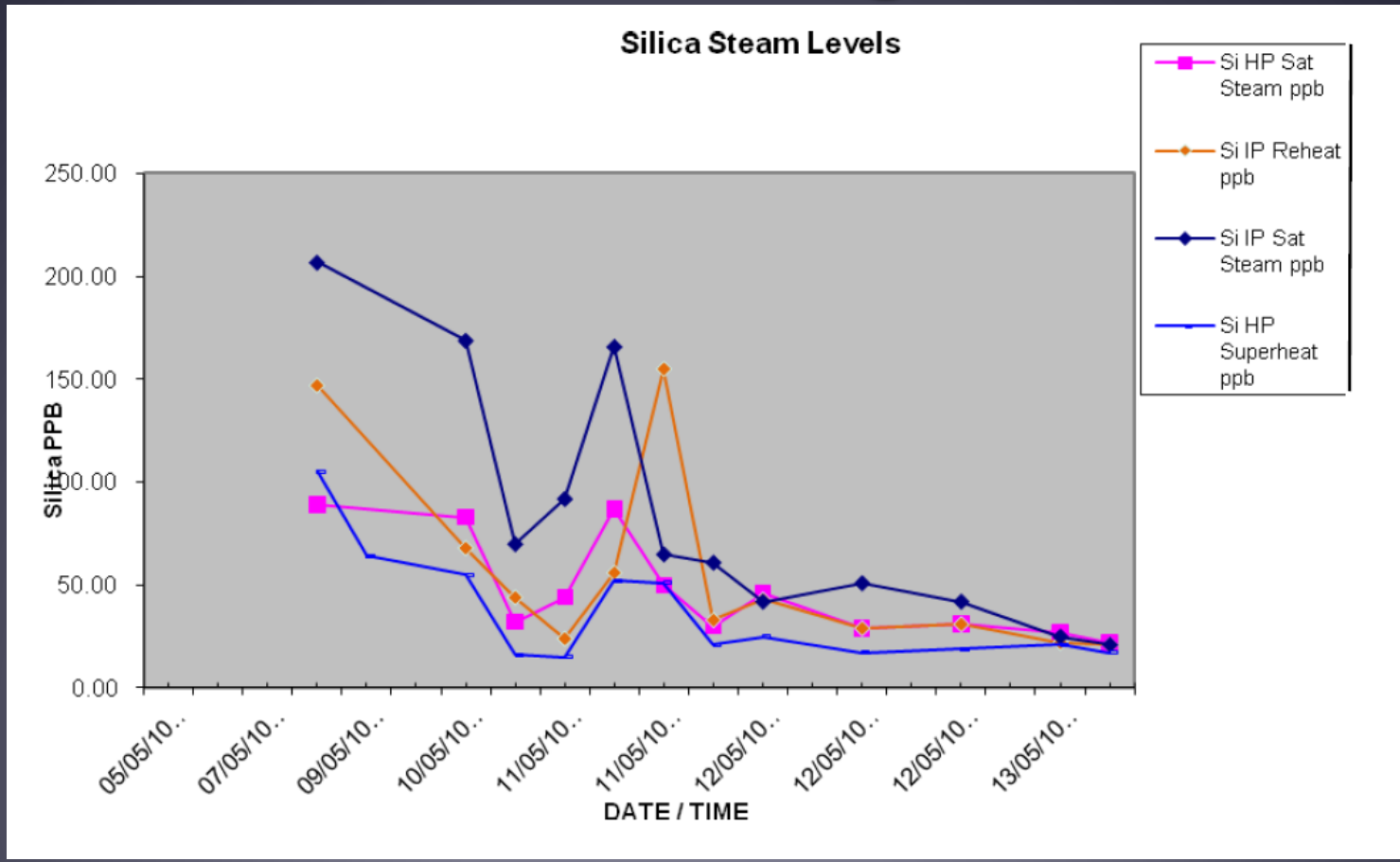


Figure 2 — *Maximum boiler water silica permitted at various pressures to keep steam silica at or below 0.02 ppm*

From Nalco Technical Literature

Silica Reduction during Steamblows



Steam silica concentrations reported during base load steamblow through temporary bypass to a condenser

Cation Conductivity

- Low cation conductivity is also a critical goal to be achieved prior to initial steam admission to the steam turbine.
- Residual contamination from the fabrication of the ACC is a significant source of contamination that leads to high cation conductivity readings in the steam cycle.
- A key objective of the initial steam flush of the ACC is to wash away harmful salts and to form a stable passivation layer on the ACC carbon steel surfaces.

From a Construction to an Operational Environment

- At the completion of construction, the metal surfaces of the ACC are in equilibrium with the construction environment.
- BES&T experience has shown that to achieve a rapid transition from a construction environment to an operational plant environment, application of normal steam cycle chemical treatments is not the most effective approach.
- Application of a specific steam cycle chemistry designed to convert surfaces covered in atmospheric oxides to the passive oxides needed for normal plant operation is a more effective solution.

Conversion of Iron Salts to Insoluble Magnetite

- Iron oxides formed by atmospheric corrosion have considerable solubility in steam condensate.
- At a high pH, these oxides are converted to iron hydroxides.
- The iron hydroxides are converted to insoluble magnetite by a condensation reaction to form a iron oxide polymer of Fe_3O_4.

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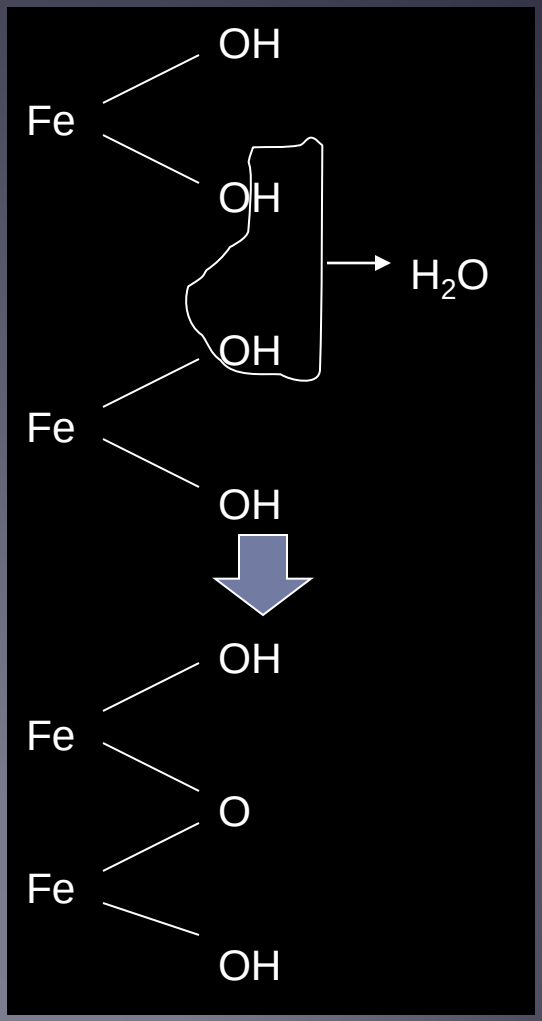
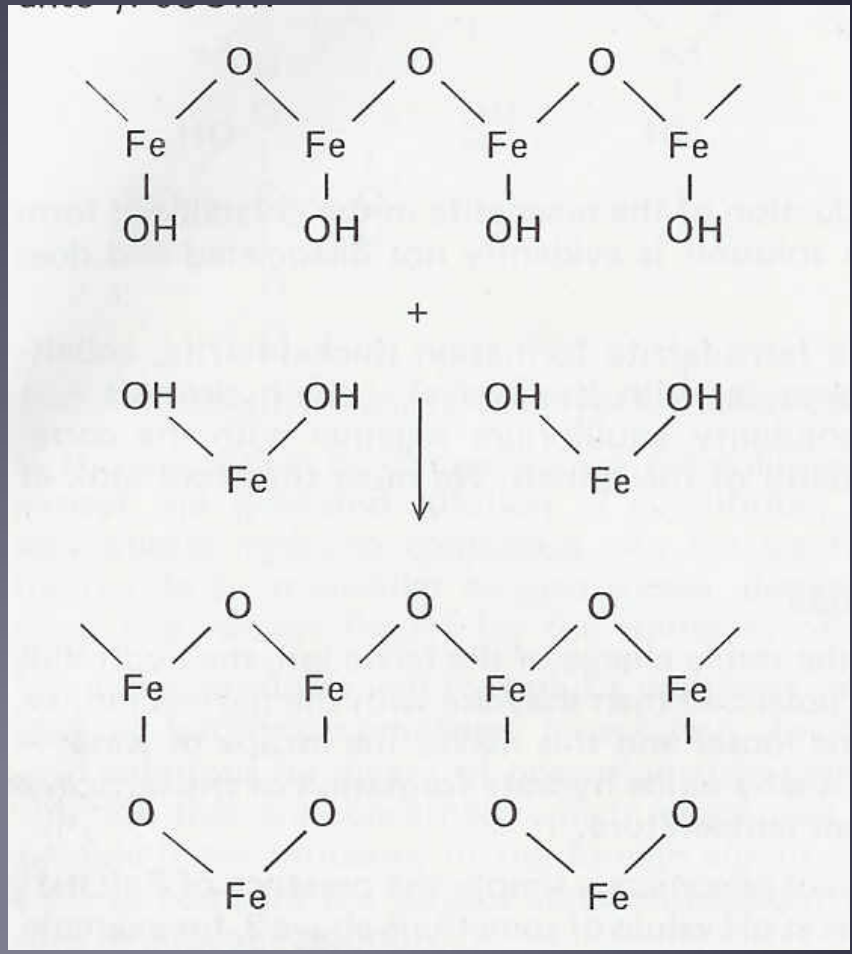
Magnetite Formation

- Formation of iron salts is the common result of atmospheric corrosion of new steel surfaces
- For reliable commercial operation of an ACC, iron salts must be replaced by insoluble magnetite
- Magnetite is form from iron salts by a condensation reaction



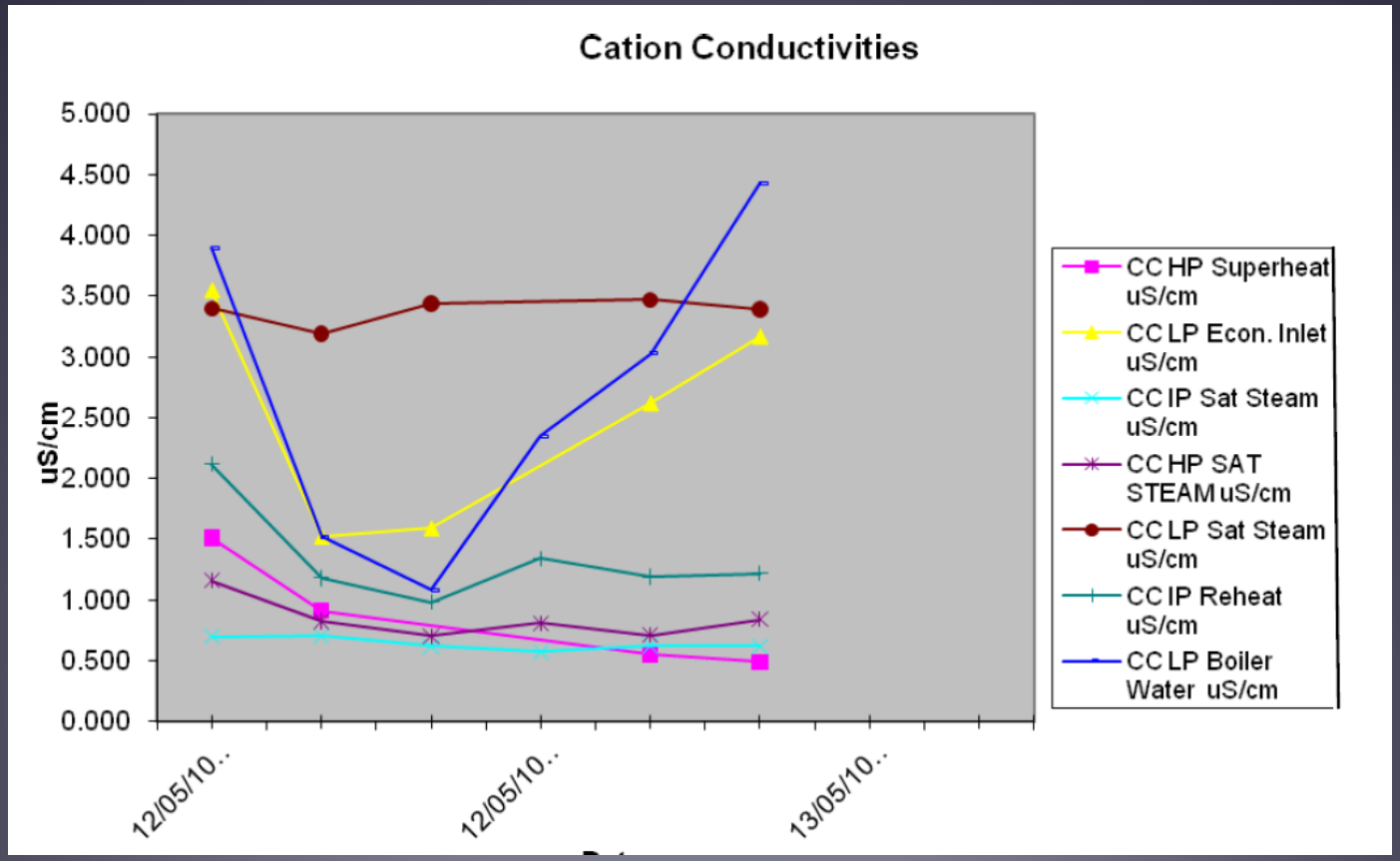
Magnetite Chemistry

- Magnetite is an inorganic polymer of iron hydroxides
- Magnetite is formed and at elevated pH values
- The oxidation/reduction potential (ORP) of the system must be control to form and maintain the insoluble magnetite layer
- Until a stable magnetite layer is established steam cycle surfaces are capable of generating additional contamination into the system



Steam System and Condenser Passivation

Cation Conductivity during Steamblow



Cation conductivity reduction during base load steamblow through temporary bypass to condenser

Achievement of Steam Purity

- ACC case study example: Heron II Power Plant
- HRSGs were protected by VPI specified by HRSG buyer.
- ACC, condensate, feedwater and HRSGs were flushed with high velocity water.
- No chemical cleaning was performed.
- Steam purity was achieved with a total of 113 fired hours including 24 hours at base load.

Conclusion

- An ACC represents a significant potential source of steam cycle contamination.
- With aggressive mechanical flushing and chemically assisted steam flushing, all contamination present in an ACC can be quickly removed.
- The metal surfaces of a new ACC can be treated to convert the ACC from a condition that is in equilibrium with a construction environment to an environment consistent with normal steam cycle operation.