Fehr Solutions, LLC

Water Treatment Services and Consulting

Maintaining the water side of your ammonia refrigeration system

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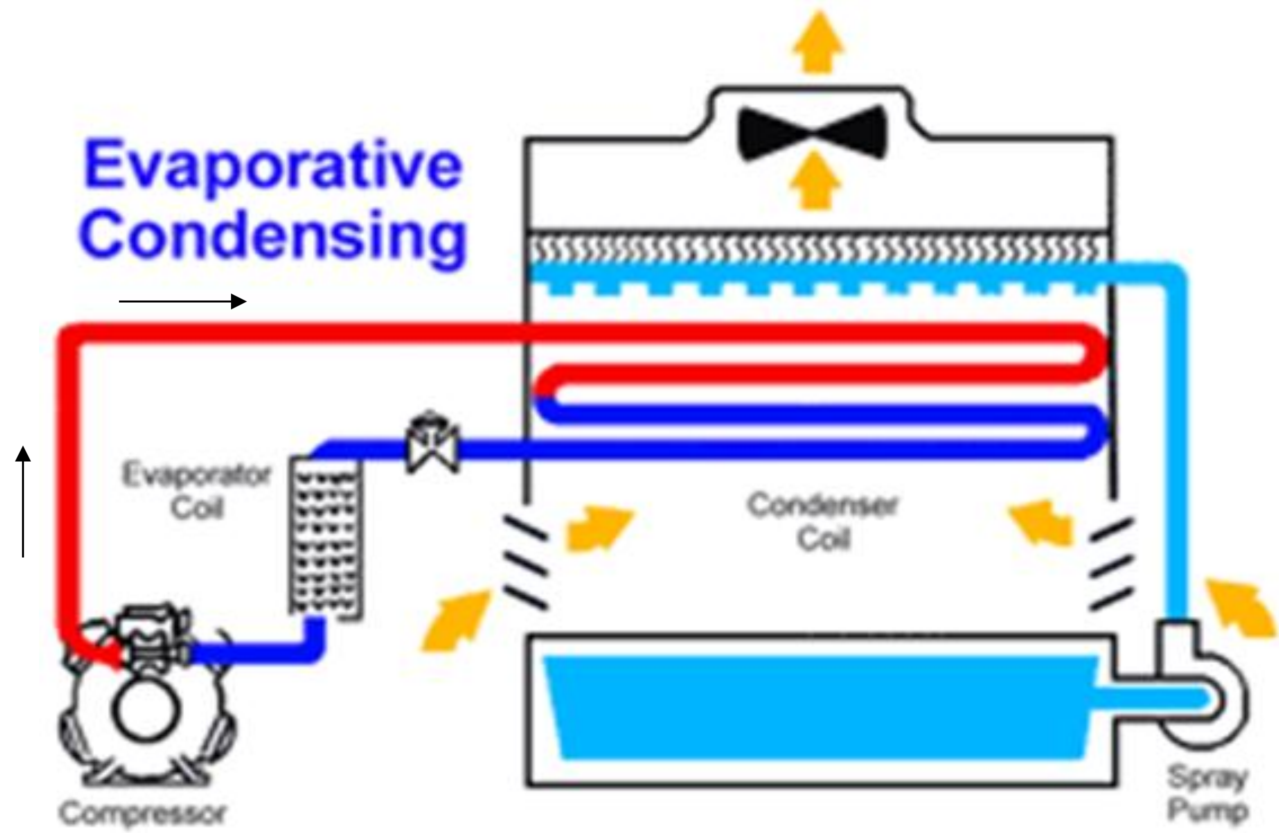
Why do we have cooling/ condensing towers?

- (Good question given the spring we are having in MN)
- To help cool water that is being used to pull heat from equipment or a process (ie chillers)
- Help cool gaseous ammonia and make it easier to compress
- Improve cooling and refrigeration efficiency
- During much of the year, air cooling is enough to keep head pressures down.
- However, depending on load and airflow, we can see folks running water at temps as low as 30 F.
- >95 % of the cooling comes from water evaporation, not from the rise in the water temperature

Evaporative Condenser



Ammonia (or another compressible gas) is cooled as water evaporates from the surface of the condenser coil

Water chemistry concerns

- Scaling
  - Usually due to calcium and magnesium in the water supply
- Bacterial growth
  - health/safety concerns
  - Corrosion issues
- Corrosion
  - Loss of galvanization
  - Corrosion of base metals
  - Ammonia leaks!

Issue #1: Scale

- Scale is mostly calcium carbonate.
  - Unsoftened water contains both calcium and magnesium. Both can lead to scale formation.
- Unlike sugar or salt, calcium carbonate is much less soluble at higher temperature.
- As a result, scale typically deposits on surfaces that are the warmest (the condenser coils!).
- In condenser towers, this can significantly reduce cooling efficiency
  - Scale on the tubes forms an insulating layer on the condenser tube and prevents the water (or air) from cooling the ammonia efficiently
  - Results in high head pressure and increased energy consumption

Scale: It can happen to you!

Methods of Scale Prevention 1

- Feed Soft water
  - Remove all the calcium and magnesium before you feed it to the towers
    - Can create corrosion issues
- Cycle the condensers down:
  - Increase the blowdown rate lowering the conductivity so you don't exceed the solubility limit of calcium carbonate
    - Water usage is often very high
- Reduce the pH by dosing acid:
  - Removes the carbonate (other half of scale) and increases Calcium solubility but you must balance against corrosion.
  - Adjust pH down using controlled dosage of sulfuric acid to maintain the pH at 7.3-8.1
    - Can risk corrosion as the pH is adjusted down

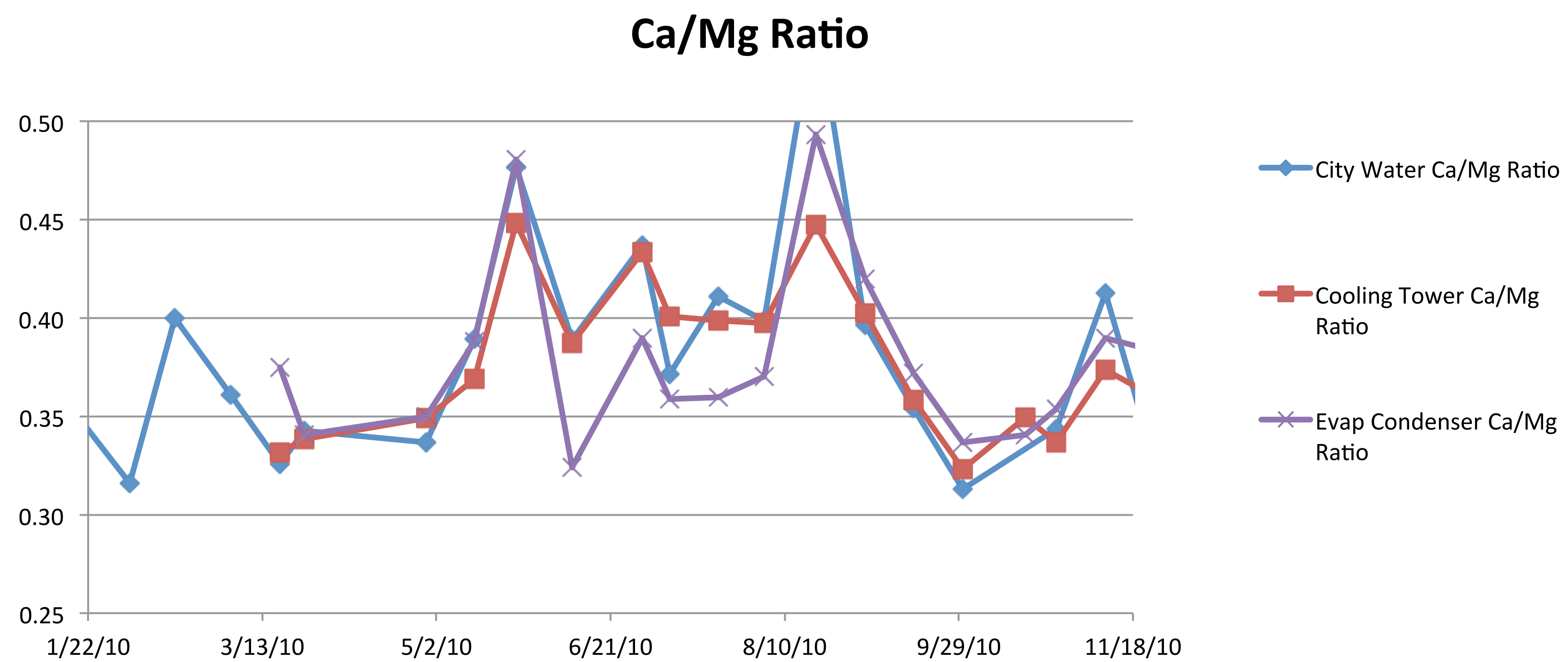
Methods of Scale Prevention 2

- Add chemicals to prevent scale from forming and keep particles suspended and flushed out with the blowdown water
  - Scale inhibitors: These are usually phosphonate-based scale inhibitors Polymer: low mw polyacrylate is usually is added to keep particles suspended and flushed out
  - These chemicals are generally used together and only work up to about 400 ppm of calcium with good flow.
- Use of mechanic devices to prevent scaling
  - The performance of these devices seems to vary significantly with the water chemistry.
  - They do not appear to be broadly applicable
- Combinations of the above approaches
  - For example pH control with scale inhibitors

Is your treatment method working?

- At high cooling load you should test daily to verify that your treatment program is working.
  - Is the Ca/Mg ratio of your tower water in balance with the make up water?
    - If not, and the ratio is lower than the make up water, you are likely scaling.
  - Are you within your conductivity limits?
    - This is dictated by your calcium levels and is usually the primary test done to look for potential scaling
  - Is the pH at appropriate levels?
    - The amount of calcium you can sustain varies with pH
      - 900 ppm of Ca is OK if you are at a pH of 7.8, but not at 8.6
  - Are your treatment chemicals dosed at appropriate levels
    - Test for polymer and phosphonates
  - Soft water program – is the makeup water soft?

Ca to Mg Ratio



- Here we found a water flow issue (plugged pump screen) in evaporative condenser

Scale Removal

- Can be difficult
- Badly scaled condenser can be rehabilitated in a number of ways
  - Feed soft water: if softening capacity is available this can rapidly clean up a condenser
    - Be mindful of white rust
  - Lower the pH
    - Treat with acidic de-scaling product for a day or two
    - Run at a lower pH long term – ie 7 instead of 7.9 – in order to slowly dissolve scale
    - Be mindful of corrosion issues
  - Mechanical removal
    - Pressure wash
    - CO_2 blasting

Scaling considerations at Season Start up

- Consistent water flow over all the tubes or fill in the condenser or cooling tower (see earlier photo)
  - Nozzles or the holes in a distribution pan should be inspected and cleared of debris so water can flow evenly over all surfaces
- Debris should be removed from the bottom of the sump as part preseason preparation. (minimum)
  - Debris (leaves, dirt, scale) can be plug nozzles or the holes in a distribution pan leading to uneven flow
  - Low flow causes excessive **localized** evaporation and over concentration of scale forming compounds
    - Evaporation to dryness will leave scale behind
  - Nozzles should be inspected every couple of weeks during the cooling season
- Chemicals carried over from last season still in spec
  - No gelling or precipitation
  - Won't be as effective and may not pump well
- Inspect chemical pumps for proper operation
  - Deliver chemical and hold prime

Issue #2: Bacterial Growth in the water

- The temperature of water in condenser or cooling tower is just the right temperature to grow all kinds of things
  - Bacteria
  - Algae
  - "biofilms"
- Biocides must be added to prevent fouling
  - 12.5% sodium hypochlorite (aka bleach) is often fed at a rate to maintain 0.1-0.5 ppm of free available chlorine
  - Other biocides are available, but are often very expensive
  - Use of mechanical devices to control bacterial growth
    - Recent reports suggest these claims do not stand up to scientific scrutiny.
- Validation of biological control program should be done at least monthly using bacterial growth dip slides.

Issue 3: Corrosion

- Most cooling towers and evaporative condensers are constructed of galvanized steal.
- In galvanization, zinc is deposited onto a mild steel surface by hot dip process (HDG)
- Usual thickness is only about 4 mils (4/1000 of an inch)
- Still able to provide excellent resistance to corrosion – provided the integrity of the zinc coating is maintained

Hot Dipped Galvanizing - Safety?

- 2.35 oz's of zinc per square foot - G235 is standard
  - Approximately 4 to 5 mils thick (thousandths of an inch)
- The zinc coating is protecting the mild steel tubes
  - They must be zinc coated to protect from atmospheric corrosion
  - Wet/Dry conditions when systems are not operating would quickly corrode any exposed mild steel
  - If the zinc is removed the mild steel will corrode and cause "safety" issues…

How stable is the zinc layer?

- Initial passivation leads to the formation of a layer of zinc carbonate which forms a protective layer on the surface of the zinc.
- Well-passivated zinc is resistant to chemical corrosion and formation of white rust
  - Zinc is present because it is a good corrosion inhibitor
    - Sometimes called “sacrificial” because it is designed to “corrode” instead of the underlying mild steel
    - Some sacrifice is expected - particularly during intermittent operations (spring/fall) or start up

How do I know if I'm losing zinc?

- Method #1
  - Measure zinc in the condenser water
    - Zinc levels consistently > 0.15 ppm suggest that zinc is being lost from the condenser surfaces at an accelerated rate
    - Should be trended over time
    - Your water treatment provider should be doing this as part of their service program.
- Method #2
  - Visual inspection of condenser for evidence of white rust or other zinc products

Passivation and White Rust

- White Rust is a condition where an unstable zinc hydroxide is formed instead of the stable zinc carbonate
- The stable zinc carbonate is a dull gray and dense
- The unstable zinc hydroxide (white rust) is fluffy and sloughs off easily.

What kind of guidance do the condenser manufacturers give?

- Passivate before start up
  - Generally some sort of phosphate based treatment
  - Hardness must be present
    - Working on laying down a microscopic Calcium Carbonate/ Calcium Phosphate layer that stabilizes and hardens the zinc.
  - pH is maintained around 8.2
  - Unit under little or no load
- After that……….

From the EVAPCO Bulletin

- Water Chemistry that **prevents WHITE RUST:**
  - **1. A neutral pH between 7.0 to 8.0**
  - **2. Hardness of 100-300 ppm measured as $CaCO_3$**
  - **3. Alkalinity of 100-300 ppm measured as $CaCO_3$**
- Water Chemistry that **promotes WHITE RUST:**
  - **1. pH levels greater than 9.0**
  - **2. Calcium hardness as $CaCO_3$ less than 50 ppm**
  - **3. Anions of sulfates, chlorides and nitrates greater than 250 ppm**
  - **4. Soft water with calcium hardness ($CaCO_3$) less than 50 ppm combined with a high alkalinity greater than 300 ppm ($CaCO_3$) and a pH greater than 8.3.**

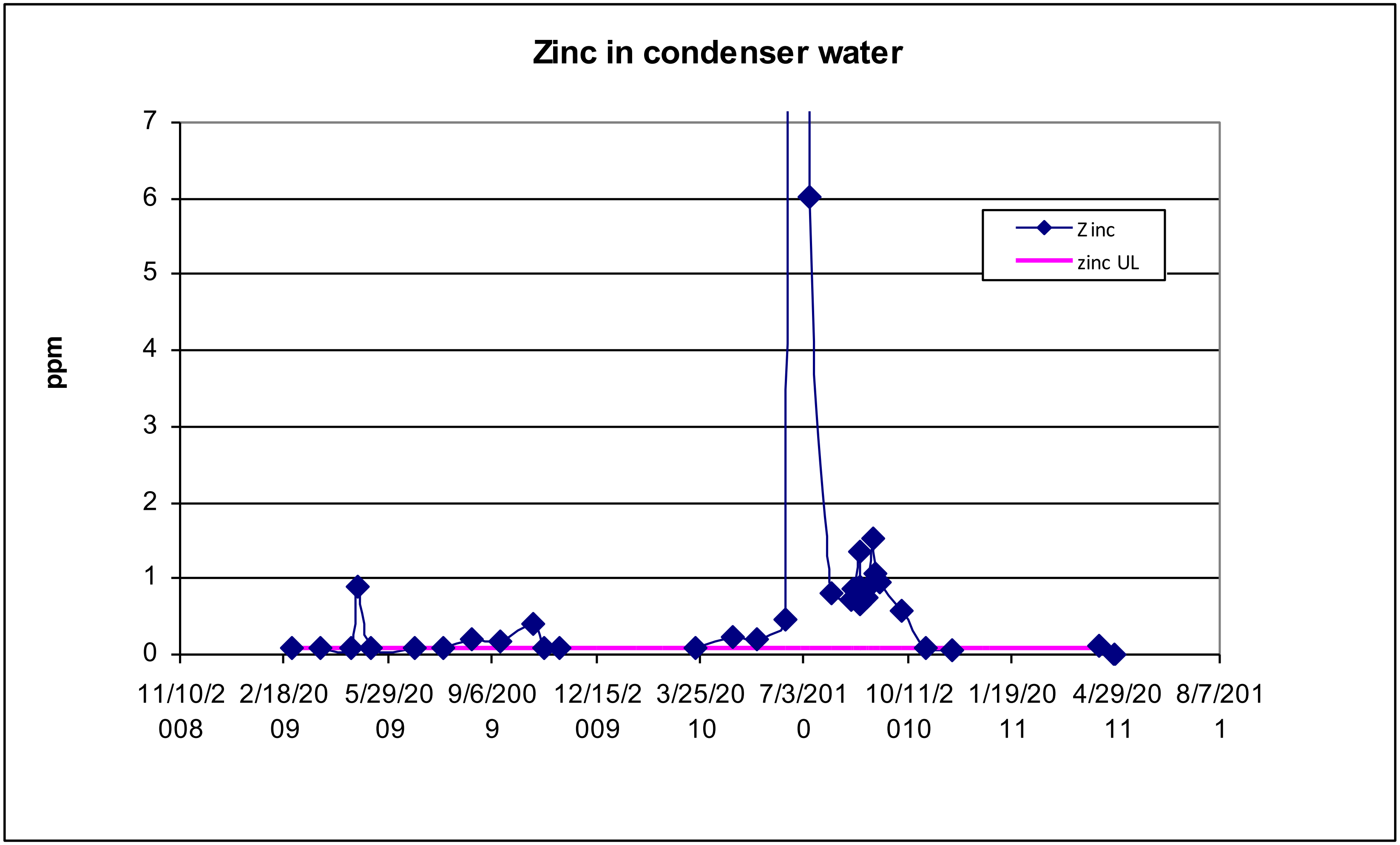
Nearly impossible to meet these specs in most waters in Minnesota

- Acid feed - raises sulfates well above 250 ppm
- Soft water - increases pH and carbonate alkalinity above recommended range
- Doing Neither - wastes water and increases chemical costs

What do you do?

- Water chemistry throughout the state is highly variable
  - Operating conditions that give good results in one area may not work well in another (depends on age of condenser and history)
- We recommend the following:
  - Monitor zinc levels both through measurement and through visual inspection
  - Modify water chemistry to minimize zinc levels
- Initial "Re-Passivation" each season
  - Maintain Calcium below 400 ppm as $CaCO_3$
  - No pH control (to prevent sulfates from getting to high and causing zinc to become sacrificial)
  - Operate this way for 2 to 4 weeks during intermittent operation
    - Identify water chemistry that minimizes zinc

Example of a condenser with zinc corrosion issues



Protect your investment

- Work with your water treatment supplier to ensure the right metrics are being monitored to assess:
  - Scale control program
  - Biological control
  - Corrosion control Is zinc in the water measured routinely?

- Monitoring the right parameters is just the first step.
  - Look at your service reports
  - Is the data being analyzed and trends acted upon?

- Don’t be afraid to ask questions of your water treatment suppliers
  - You pay the bills
  - It’s up to you to make sure you get as much value as possible

Performance Metrics That Drive Program Selection

- Fehr Solutions recommends that condensers are fully tested every two weeks to ensure the treatment program is meeting performance metrics

parameter	limit	why
conductivity	Determined by Calcium/Silica	Must be well controlled to prevent scale
pH	If controlled then between 7.0 and 8.0	Scale forms more readily at high pH (>8)
Calcium hardness	No pH control 400 ppm limit pH control 1,000 ppm limit	Primary foulant
Magnesium hardness	report	We then check the ratio of Ca to Mg to make sure it is the same as the make up water
Free Chlorine and Bacteria	0.1-0.8 and <1,000 cfu/ml	Free chlorine prevents bacterial growth. Monitor with dip slides at least monthly
zinc	In most cases < 0.1	Elevated zinc indicates we are losing galvanization
Treatment chemicals	Set by company	Verify that proper treatment levels are present

Questions?

- Contact us at www.FehrSolutions.com
- Or in Minnesota contact us directly

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