Introduction

Water treatment has been described as White Magic but it only becomes White Magic if you let it happen or if an unscrupulous supplier leads you to believe it is so. After working in the Water Treatment Industry for over 21 years and while on sabbatical leave a number of years ago following the takeover of one multinational water treatment company by another I decided to try to simplify the issues of water treatment for our industry. This outline of water treatment for various types of systems is designed to give the reader an idea of the risks that are involved in each type of system and to help them to better understand the risks associated with each type of system, the treatments and services available to eliminate or minimise these risks.

It is not meant to be an all encompassing guide for every scenario and this is where the expertise and the experience of the Water Treatment Company comes in. It is however designed to help you the reader to be able to check if the proposals being submitted to you will really help to not only protect your systems but will also help you to reduce energy and water throughout your plant while minimising both health and environmental risks on your site.

As we called our company *AquaChem Ltd* we called our guidelines “Simplifying Water Treatment the *AquaChem* Way”. We have updated these guidelines as products and services change and will continue to do so.

We hope you find these guidelines of help.

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Managing Director
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General Causes of Corrosion and Fouling in Heating and Chilled Water Systems

- Quality of make-up water e.g. low hardness and low alkalinity increases risk of corrosion
- Low pH also increases risk
- High level of solids increases risk of erosion damage
- High chloride increases risk of corrosion especially on stainless steel
- Surface deposits due to insufficient pre-cleaning or on-going corrosion problems
- Oxygen ingress especially at pumps
- Welds
- Proximity of dissimilar metals
- Discontinuity of corrosion inhibitor film due to low or varying treatment levels
- Low flow areas
- High flow rates which can strip off inhibitor film
- Presence of biological contaminants such as bacteria and fungi can cause problems especially in the case of chilled water systems and heating systems that are used intermittently
- Use of antifreeze such as mono ethylene or propylene glycol on chilled systems while offering protection from freezing will actually encourage the growth of fungi and bacteria under which corrosion can occur even if correct levels of inhibitors are maintained in the systems.

System Design and Operation to Minimise Corrosion

- Use metals with lowest risk of galvanic corrosion where costs allow
- Use seals and gaskets from materials which do not corrode such as plastic and rubber
- Ensure that seals and gaskets are suitable for the temperatures the systems are designed to operate at
- Ensure that you use seals and gaskets that are not affected by water treatment chemicals
- Re-circulation pumps should be designed to give flow rates as near to 1 metre/second as possible
- Minimise dead legs and low flow areas
- Pre-clean each system using proprietary chemical blends which also have an in-built inhibitor such as ChemSperse 105
- Pre-cleaning to be carried out in line with Method Statement such as the one enclosed which fully complies with BSRIA guide for Pre-commission Cleaning or new systems
- Immediately system is pre-cleaned add recommended quantity of corrosion inhibitor such as ChemHib 101, 201, 301 or 401
- Use a biocide on all chilled systems or if a heating system is likely to be prone to bacteria growth
- Ensure that a water treatment company provides certification to confirm that all pre-cleaning and inhibition is carried out to a satisfactory standard
- Method of dosing can be automatic or semi-automatic depending on site requirements
- Simple on-site testing for inhibitor levels to be carried out at least once/month

- Water Treatment Company to test each system at least quarterly with the following minimum analyses on each system:
    - inhibitor levels
    - iron
    - conductivity
    - pH
    - bacteria levels where there is a risk of bacteria growth.

  In addition tests for Aluminium and Copper should be carried out on systems containing these metals. Strict pH control of 6.5 to 8.3 maximum must be adhered to for all systems containing Aluminium with inhibitors such as ChemHib 201 or 301 which have specific Aluminium inhibitors only, being used.
- Corrosion coupons of system metals can be used especially on high risk systems to provide regular monitoring of corrosion rates with a target of 2 to 5 mils/year for iron which is generally the metal which gives most problems
- Schedule regular system inspections
- Paint metal make-up tanks with protective paints such as Berger's Apexior which are suitable for the temperatures involved
- Where parts of the system have to be replaced or extended ensure that the newly added metal does not increase the corrosion risks
- Fit water meters or ensure that Water Treatment Company advises on high system losses which will be indicated by high chemical usage
- Modify systems to maintain losses below 0.5%/week.

General Causes of Scale on Heating Systems

- Quality of make-up water - high hardness greatest risk
- High pH increases risk
- Higher levels of solids
- Temperature of system operation
- High water losses of greater than 0.5% of volume/week

System Design and Operation to Minimise Scale Build-up

- Examine option of pre-treatment such as softening or reverse osmosis for high hardness waters
- Reduce water losses to less than 0.5% of volume/week
- Re-circulation pumps should be designed to give flow rates as near to 1 metre/second as possible
- Minimise dead legs and low flow areas
- Pre-clean each system using proprietary chemical blends which contain polymers/dispersants such as ChemSperse 105 with work being carried out in line with Method Statement enclosed
- Immediately systems are pre-cleaned use inhibitors which contain polymers/dispersants such as ChemHib 201 or ChemHib 301 which help keep hardness in suspension
- If hardness of make-up water is greater than 60 mg/l consider the installation of a water softener
- Ensure that a water treatment company provides full certification to confirm that all pre-cleaning and inhibition has been satisfactorily carried out
- Method of dosing can be automatic or semi-automatic depending on site requirements
- Simple on-site testing to be carried out at least once/month

- Water Treatment Company to test each system at least quarterly with the following minimum analyses on each system:
    - Check that pre-treatment plant is operating to target results
    - Inhibitor levels
    - Conductivity
    - pH
    - Hardness levels
- Schedule regular system inspections
- Fit water meter to check system losses
- Modify system to maintain system losses below 0.5%/week

General Causes of Corrosion, Scale and Fouling on Open Re-circulating Cooling Systems.

Causes of Corrosion

- Quality of make-up water - low hardness and low alkalinity means increased corrosion risks
- Pre-treatment such as softening increases risk
- Low pH increases risk
- High chloride increases risk especially on stainless steel
- High bacteria levels result in underdeposit corrosion
- High suspended solids can also result in underdeposit corrosion
- Proximity of dissimilar metals
- Low flow areas
- Discontinuity of corrosion inhibitor film due to varying or low treatment levels
- High flow rates which can strip off inhibitor film
- Temperature of system operation

System Design and Operation to Minimise Corrosion

- Carry out full analyses of make-up water
- Ensure that system operates within recommended pH ranges

  8.3 maximum for systems containing Aluminium

  8.5 maximum for systems containing copper or brass
- Control bacteria levels to give a maximum of 10^4 organisms/ml at all times using products such as our BioChem range of biodegradable biocides
- Minimise or eliminate dead legs and low flow areas
- Use metals with lowest risk of galvanic corrosion where costs allow
- Pre-clean each system using proprietary chemical blends which have in-built corrosion inhibitors such as ChemSperse 105
- Immediately system is pre-cleaned add recommended quantity of corrosion inhibitor such as PolyChem C1033EV, C403, C503 or C903
- Ensure that a Water Treatment Company certifies that all pre-cleaning and inhibitor dosing has been completed correctly
- Liaise with a competent Water Treatment Company to design easy to operate and maintain automatic dosing and bleed-off system
- On-site testing should be carried out at least once/week covering the following analyses:
  - inhibitor levels
  - conductivity or chloride
  - bacteria levels

- Water Treatment Company to test each system at an agreed frequency with the following minimum analyses on each system:
    - inhibitor levels
    - iron
    - conductivity
    - pH
    - calcium hardness
    - alkalinity levels
    - bacteria and fungi levels

In addition tests for Aluminium and Copper should be carried out on systems containing these metals. Strict pH control at 8.3 maximum must be adhered to for all systems containing Aluminium and pH of 8.5 maximum for all systems containing copper or brass as higher pH's increase risk of corrosion

- Minimise dead legs and low flow areas
- Corrosion coupons containing system metals should be used to provide regular monitoring of system corrosion rates with a target of 2 to 5 mils/year for Iron which is generally the metal which gives most problems
- Schedule annual system inspections
- Where parts of the system have to be replaced or extended ensure that the newly added metal does not increase corrosion risk
- Ensure that a Water Treatment Company advises on how to minimise water, energy and chemical usage
- Fit make-up water meter and keep careful check on water usage

Causes of Scale on Open Re-circulating Cooling Systems

- Quality of make-up water - high hardness and high alkalinity waters increase scaling risks
- High pH increases risk
- High system operating temperatures even on medium hardness waters, 50 to 100 mg/l in the make-up, lead to increased scaling risks
- Low flow areas
- High levels of solids

System Design and Operation to Minimise Scale Build-up

- Carry out full analyses of make-up water
- Examine option of pre-treatment such as softening for higher hardness waters and for medium hardness waters where system operates at high temperatures
- Re-circulation pumps should be designed to give flow rates as near to 1 metre/second as possible
- Minimise low flow areas and eliminate dead legs
- Pre-clean each system using proprietary chemical blends such as ChemSperse 105 which contain polymers/dispersants
- Immediately systems are pre-cleaned use inhibitors which also contain polymers/dispersants such as PolyChem C1033EV, C403, C503 and C903
- Ensure that a water treatment company provides full certification that all pre-cleaning and inhibition has been satisfactorily carried out
- Liaise with a competent water treatment company to design an automatic dosing and bleed-off system which is easy to operate and maintain

• on-site testing should be carried at least once/week and include the following analyses:
  - calcium hardness or conductivity from pre-treatment plant
  - inhibitor levels
  - system water conductivity
  - bacteria levels which should be at or below 10^4 organisms/ml maximum

• Water Treatment Company to test each system at an agreed frequency covering the following minimum analyses on each system:
  - inhibitor levels
  - calcium hardness
  - alkalinity levels
  - pH
  - conductivity
  - calcium hardness balance

• Schedule regular system inspections
• Ensure that Water Treatment Company advise on how to minimise water, energy and chemical usage
• Record water usage

Causes of Fouling on Re-circulating Cooling Systems

Biological Fouling

• Quality of make-up water e.g. high bacterial, fungal or algae levels increase potential for biological fouling
• Temperature which encourages growth of certain organisms such as the Legionella bacteria which grow mainly between 20^oC and 47^oC but can survive up to near 60^0C

- Gaskets, seals, coating and jointing materials can encourage growth
- Chemical inhibitors which contain products such as Nitrites and Phosphates can also encourage growth
- Sunlight, especially, encourages algae
- Distance from exhaust air outlets
- Presence of high levels of inorganic impurities
- Presence of oxygen and carbon dioxide
- System pH's of 6.5 to 8.5, which most cooling systems operate within, is ideally suitable for bacterial growth
- Water flow rates affect growth rates as low flow rates encourage growth

System Design and Operation to Minimise Biological Fouling

- Ensure that make-up water contains low levels of micro-organisms
- Use a pre-treatment system, if required, to reduce levels of organic and inorganic impurities
- Use seals, gaskets and jointing materials which do not encourage growth of organisms
- Ensure that the scale and/or corrosion inhibitors used to treat the system do not encourage growth of micro-organisms
- Use cooling systems which minimise the amount of sunlight that comes in contact with the water
- Ensure that the system is kept as far away as possible from sources of contamination including exhaust air outlets
- Eliminate deadlegs and ensure that system flow rates are near to 1 metre/second
- Liaise with a competent water treatment company to design a biocide dosing system which will automatically and accurately dose biocides, preferably, direct from a chemical drum so as to eliminate handling

- Pre-clean system using proprietry chemical blends which contain polymers/dispersants such as ChemSperse 105
- Immediately the system is pre-cleaned ensure that it is dosed with the recommended quantity of biocides such as from the BioChem range
- Ensure that a water treatment company provides certification that all pre-cleaning and inhibition has been carried out to a satisfactory standard
- On-site biological testing should be carried out at least once/week with bacteria levels being kept at or below 10^4 organisms/ml
- Water treatment company should also check bacteria levels and advise on changes required to biocide dosing regime should bacterial counts show an upward trend
- Schedule inspections at least annually
- Maintain system conductivity as high as possible as this will reduce water and keep biocides in the system for as long as possible thereby increasing their effectiveness rate
- Liaise with the Water Treatment Company on how to minimise water usage

General Fouling of Re-circulating Cooling Systems

Causes of General Fouling

- Quality of make-up water e.g. if water contains high levels of suspended matter such as dust, silt or clay it increases the potential for fouling
- Location of the plant
- Biological matter such as pollen and insects
- Contamination from the process being cooled
- Oil, grease and jointing compounds
- Deadlegs and low flow areas

System Design and Operation to Minimise General Fouling

- Locate cooling systems in areas less prone to airborne contaminants
- Consider use of pre-filters where make-up water containing high suspended matter has to be used
- Alternatively use smaller automatic side-stream filters (which only require 5% of irculating water to go through them) to remove suspended matter from re-circulating later
- Design/re-design system to minimise process contamination
- Eliminate deadlegs and low flow areas
- Design system to have flow rates of 1 metre/second
- Minimise amount of grease and jointing compounds
- Use products such as PolyChem C1033EV which contain antifoulants or dispersants

Assessing and Minimising the Risks of Legionnaires Disease on New and Existing Systems

General Conditions in which Legionella Bacteria Grow and Cause a Health Risk

- Water temperatures between 20^{0} C to 47^{0} C
- pH levels of 6.0 to 9.0
- Presence of other bacteria
- Presence of other deposits such as scale
- Presence of iron
- Presence of nitrogen compounds
- Ability of system to produce aerosol droplets such as those produced by cooling towers, spray taps, misters, pressure washers, ornamental, safety and domestic showers.
- Deadlegs and low flow areas

Assessing and Minimising the Risks

New Systems

- Full water analyses
- Design system to minimise risks such as ensuring Cooling Towers contain efficient Drift Eliminators to minimise aerosol production
- Water tanks should be designed to prevent contamination
- Calorifiers should be designed to heat water to 60^{0}C without stratification
- Tanks and calorifiers should be accessible for cleaning
- Ensure systems are pre-chlorinated to a set standard such as BS 6700:1 for New or Refurbished Buildings
- Ensure that the Water Treatment Company or whoever carries out the pre-chlorination certifies that this work has been carried out to BS 6700 or equivalent standard
- Ensure that each system is immediately treated with a full programme to prevent scale, corrosion and control bacteria levels within maximum recommended limits for each system
- Weekly on-site system analyses as agreed with Water Treatment Company
- Maintain records of all tests and actions
- Water Treatment company to carry out independent tests on each system at agreed frequencies
- Carry out system cleaning and sterilisation once every six months on cooling towers and once per year on all other systems which operate within the temperature range of 20^{0}C to 47^{0}C. Work to be carried out in line with a written specification such as *AquaChem's* **"Cleaning and Sterilisation of Water Systems Specification"**
- All Cleaning and Sterilisation work to be certified
- Carry out Legionella tests on cooling towers each quarter and on all other systems once per year

Existing Systems

- Full water analyses of both make-up and system waters
- Carry out full **Risk Assessment** to comply with **Irish Safety, Health and Welfare at Work (Biological Agents).Regulations 1994 and 1998 and/or the National Disease Surveillance Centre "The Management of Legionnaires Disease in Ireland" Guidelines 2002 and UK L8 Guidelines**. This will involve areas such as system inspections, checks on water testing records, cleaning, maintenance, dosing and control systems, temperature measurements and operation of pre-treatment systems together with information on system volumes and location. Type of calorifiers and any evidence of heat stratification should also be examined. Based on the Risk Assessment a full report will be prepared detailing weekly, monthly, quarterly, six monthly and annual procedures required to minimise the risks for each system
- Complete treatment programme should be in place to minimise biological growth, scale and corrosion
- Chemical dosing (and bleed-off in the case of re-circulating cooling systems) should be carried out automatically to ensure safety, accuracy and consistency
- Regular on-site testing with results recorded and action taken documented at least weekly - tests as for scale and corrosion prevention
- Full on-site independent tests by Water Treatment Company for scale, corrosion prevention and control of microbiological growth with corrective action fully documented
- System Cleaning and Sterilisation every 6 months for cooling towers and annually for all other systems which use water between 20^{0}C and 47^{0}C with full certification afterwards
- Legionella tests each quarter on cooling towers and once/year on all other systems at risk

General Causes of Scale on Steam Systems

- Hardness in make-up water
- High alkalinity and dissolved solids
- High pH

System Design and Operation to Minimise Scale

- Pre-treatment of make-up water using Base-exchange softeners if hardness removal only required. Use Reverse Osmosis (RO) if make-up water contains high alkalinity and high dissolved solids. R.O. treated systems minimise blowdown and chemical usage.
- Ensure that boilers are pre-cleaned using proprietary cleaners such as AquaChem C32
- Immediately systems are pre-cleaned use full water treatment programme
- Ensure that a water treatment company provides full certification that all pre-cleaning and inhibition has been satisfactorily carried out
- Use supplementary treatment to prevent treated feedwater from forming scale or sludge
- Design or modify steam system to maximise condensate return which
  reduces risk of scale
  reduces blowdown and energy usage
  reduces chemical usage
- Use automatic dosing and blowdown systems to control chemical dosage and blowdown in line with steam usage
- Control boiler Total Dissolved Solids (TDS) at maximum level recommended by manufacturers

- Regular on site tests for
    - Alkalinity
    - Phosphate/sludge conditioner
    - Total Dissolved Solids
    - Feedwater hardness and pH
    - Pre-treatment plant hardness or conductivity

- Water Treatment Company to test each system at an agreed frequency for the following minimum analyses
    - Alkalinities
    - Phosphate/sludge conditioner
    - Total Dissolved Solids
    - Feedwater hardness and pH
    - Pre-treatment plant hardness or conductivity
    - Raw water make-up hardness, pH and conductivity

- Schedule regular system inspections with full reports and recommendations
- Ensure that the water treatment company advises on how to minimise water, energy and chemical usage

General Causes of Corrosion on Steam Systems

- Use of artificially softened/treated water as make-up
- Alkalinity levels - high alkalinity levels generate high carbon dioxide which condenses to give carbonic acid in condensate lines - low alkalinity levels give low system pH also causing corrosion
- Feedwater temperature - low temperature means higher oxygen, result of which is pitting corrosion
- Feed tank design
- Insufficient or incorrect pre-cleaning

System Design and Operation to Minimise Corrosion

- Ensure that systems which use feed tanks are designed so as to give good mixing of condensate with feedwater. Condensate to be fed down into tank at two thirds of the way and sparged
- Water supply to boiler from feed system to be at opposite end to the supply of cold water to the feed tank
- Where de-aerators are used oxygen scavengers dosage to be to de-aerator sump
- Where feed tanks are used oxygen scavengers dosing to be direct to feed tank at a point of good circulation below the water line. This will give the chemical time to remove the oxygen before it gets to the boiler. It will also help to protect the feed tank and feed lines
- Alkalinity treatment where possible should also be dosed to the feed tank to give correct pH for protection of feed tank and feed line - ideally at least pH of 7.5 to 8.5

- For pre-treatment systems such as De-alkalisation or De-mineralisation plants ensure that caustic neutralisation system is designed to give a pH of 7.5 to 8.0 consistently. **Reverse Osmosis** systems are now more commonly used to give the same quality water without having to use acid and caustic for regeneration
- Maintain feed temperature as high as possible by lagging, maximising condensate return and proper mixing of condensate and treated make-up. **Note that water at 70^{0}C has 77% more oxygen than water at 85^{0}C**
- Maintaining high feedwater temperatures will:
  - Reduce risk of oxygen corrosion
  - Reduce amount of chemical treatment required
  - Reduce the amount of blowdown if oxygen scavengers such as catalysed sulphite are used
- Ensure correct pre-cleaning with proprietary cleaners/boilout chemicals such as *AquaChem* C32
- Immediately systems are pre-cleaned use full water treatment programme
- Ensure that a Water Treatment Company or Chemical Cleaning Company provides full certification that all pre-cleaning and inhibition has been satisfactorily carried out
- Use automatic dosing and blowdown systems to control chemical dosage and blowdown in line with steam usage
- Control boiler Total Dissolved Solids (TDS) at maximum level recommended in BS 2486 guidelines
- Regular on-site tests for
  - Oxygen scavenger
  - Alkalinity
  - TDS
  - Feedwater pH
  - Pre-treatment plant hardness or conductivity

- Where there is a potential for condensate line corrosion amines should be used to protect steam and condensate lines. For Food/drinks and Healthcare plants make sure that ingredients have FDA approval
- Water Treatment Company to test each system at an agreed frequency for the following minimum analyses
    - Alkalinities
    - Phosphate/sludge conditioner
    - Total Dissolved Solids (TDS)
    - Feedwater pH and iron
    - Raw water pH and iron
- Schedule regular system inspections
- Ensure that the water treatment company advises on how to minimise water, energy and chemical usage.