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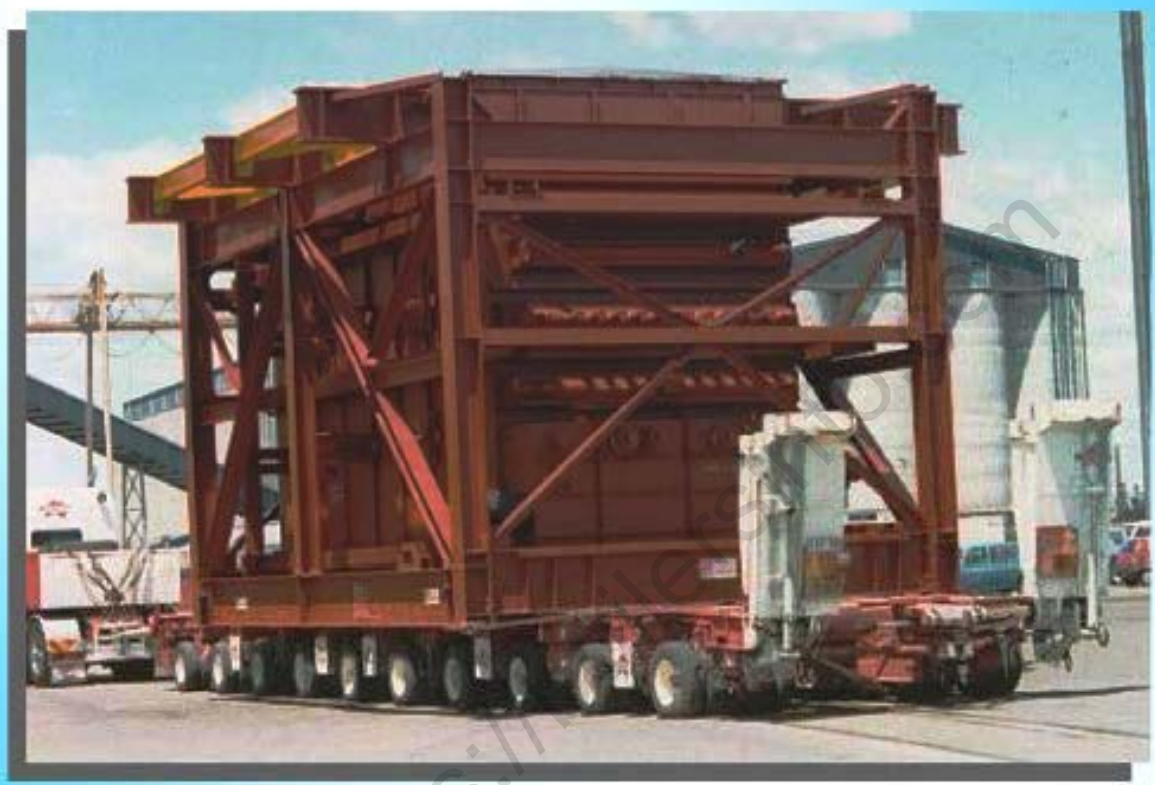

"BOILER WATER TREATMENT"- FREQUENTLY ASKED QUESTIONS

PRAVEEN VERMA

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Boiler Water Treatment Frequently Asked Questions

TABLE SHOWING LOSSES IN BOILERS DUE TO SCALE

SCALE — a silent killer to the growth of the industries, has got direct impact upon plant & equipments, operation & profitability. Its not a hidden fact to any plant engineer or maintenance department that due to slow & silent instinct nature, the scale ruins the whole system and the industry remains at stake.

In simple language the water born SCALE is caused by precipitation of Calcium carbonate that becomes insoluble at higher temperature. Scale interferes with heat transfer and reduces flow. The Boiler/Cooling systems are important equipments mostly affected by these stupedious SCALE & how it affects in case of energy consumption are shown as per following table.

TABLE SHOWING LOSSES IN BOILERS DUE TO SCALE

Thickness of Scale	Increase in Fuel Consumption due to Scale
½ mm	2%
1 mm	4%
2 mm	6%
4 mm (1/8")	10%
8 mm (1/4")	20%
16 mm (1/2")	40%
30 mm (1")	80%

Similarly it has got the adverse effect on heat exchangers and other equipments in order to reduce efficiency and increase the energy bill towards the hefty expenses. Further it's needless to say what more problem occurs and how the ignorant engineer shut down his head along with his operation due to excessive and uncontrolled Scale.

In order to go in for a systematic approach to the whole above problem the industry requires a planned water management. Planned water management means before going for any chemical treatment, make a detailed survey of the system including its design, construction material, operating temperature, analysis of make-up water, present condition of boiler & cooling tower in respect of Scaling & Corrosion followed by proper monitoring of water parameters recommended by water treatment company. Controlling of scale is not one time job, it demands a continuous treatment with proper servicing and this could be possible only through direct controlling by professionally managed manufacturing company having advance technology & International standard product. Thus can ensure you to provide a clean Scale free operation.

SAVING DUE TO CORROSION INHIBITOR TREATMENT

Its a function of water characteristics and the metal in the system, corrosion causes premature metal failures as well as the deposit of corrosion products reduce both heat transfer & flow rate.

High content of total dissolved solids (TDS), the dissimilarity of the metal, dissolved oxygen, penetrating ions like chlorides and Sulphates, the low pH and presence of various other impurities are the prime cause of corrosion in the heat exchanger i.e. boiler or cooling systems. Dependent on the type of corrosion, the heat exchanger meet with pitting problems with the eventuality of tube failure due to leakage and also meet with the problems like deposition of corrosion products on various localized sites resulting in reduction of heat transfer across the heat exchanger.

SAVING DUE TO CORROSION INHIBITOR TREATMENT

1 MIL = 1/1000 inch

Hence a heat exchanger tube of 1/8" = 125 mils Normal corrosion without/improper treatment / with soft water is 15 to 20 mpy (case --- a) corrosion with proper treatment 3 to 5 mpy (case --- b)

Normal tube life without treatment = 125/20 = 6 years (case --- a).

Tube life with treatment = 125/5 = 25 years (case --- b).

Hence depreciation of equipment like heat exchanger etc. per annum without treatment is
= 100/6 = 16% in (Case - a)

DEPRICIATION WITH PROPER TREATMENT ----- 100/25 = 4 %

Hence with proper water treatment programme depreciation cost can be reduced from 16% per annum to 4% per annum which is saving of 75%

WE FORECAST THE ANALYSIS CONSEQUENCES

There is a common question in every engineer's mind, i.e. **"ARE YOU REALLY GETTING ANY BENEFIT OUT OF YOUR PRESENT WATER TREATMENT" ??** The degree of effectiveness of the water treatment only could be judged by periodical service and its analysis report.

Successful water treatment programme for your Boilers/Cooling Systems depend upon maintaining proper concentration of chemicals and promptly taking the necessary steps to counter the adverse effects of upsets, leaks, powerfailures etc. Unless you have the services of analytical Laboratory and a chemist to supervise treatment it is advisable to engage one of the Company (Not dealer) specializing in water treatment.

The programme should include a comprehensive service package which calls for use of sophisticated equipment to continuously monitor programme performance with respect to following.

A) SCALE / CORROSION CONTROL

B) CORROSION CONTROL

C) MICROBIOCIDE CONTROL (In case of Cooling System)

For this purpose the Company should depute technically qualified representative at your premises from time to time for doing the spot analysis of various critical parameters and should adjust dosage as per prevailing water parameters.

Generally small Companies / Dealers send their representative to make regular spot checks and also submits water analysis report and chemical tests are frequently made with field test kits which at best are not very good and especially in the hands of unskilled operators results are often misleading or worth less.

METHODS OF FEEDING CHEMICALS

A SYSTEMATIC APPROACH IN TIME SAVE NINE

Due to rising cost of components of power, fuel & water and also due to shortage of these components, it is imperative that industries must look for all possible ways to minimise wastages.

This can be achieved by systematic approach and planned water management for boiler and cooling tower. One aspect of planned water man agement is to follow proper operational practices like regular dosing of chemicals, maintaining log books, monitoring parameters like pH, TDS, Hardness etc. to give only minimum blowdown and that to when required.

METHODS OF FEEDING CHEMICALS

A better procedure for adding chemicals in feed water is the continuous feeding method, which eliminates swings in concentration. All that is required a small "Day" tank that holds enough solution to last 24 hrs. A needle valve and outlet tube on the tank allows a continuous drip of chemicals into the feed water tank/basin of Cooling Tower/Boiler.

MICROBIOCIDES

A most effective method for controlling the growth of micro-organisms is slug treatment, by which a lethal concentration of toxicant is added, all at once, to the recirculating water. Continuous treatment, which is sometimes advocated, as expensive and futile; should never be used. In many instances adding biocides continuously at lower dosages only serves to engender a more troublesome and more resistant bacterial population. Because of the continuous influx of dust, it is impossible to maintain a sterile system and it is extremely expensive to try.

Best results are obtained by using two different biocides. Combination of two biocides not only keep microbiological growth under control but also help to keep the system free of fouling. Suggestively these different combination should be used alternatively and weekly without any intervention. Implementing biocides after sunset and keeping feed water pH in between 7.5 to 8.5 give best result.

OXYGEN SCAVENGER :

Oxygen Scavengers main purpose is to prevent corrosion in boiler by removing oxygen from the system. They should always be dosed on continuous basis and their solution should be prepared in a closed tank to avoid its contact with air as the level of activity is lost due to exposure of atmospheric oxygen. Their solution should be prepared in a separate tank preferably and they may be dosed separately by a metering pump if possible. The container of Oxygen Scavenger should be

kept closed all times. It is also very important that not to dissolve Oxygen Scavenger in cold water as in this case some of the dissolved oxygen in cold water itself will consume the chemical. Hence ideally condensate is useful for its dissolution as it has low dissolved oxygen due to very high temperature of condensate.

Nowadays some companies are supplying complete dosing systems on turn-key basis and you can go in for one. Looking at the benefits it provides , the cost would be nothing. In case you don't want to go in for one then you can always use a low HP domestic type pump which will take the solution to feed tank in as long time as possible.

DESCALING OF BOILER / COOLING TOWER / HEAT EXCHANGER ETC..

MAXIMUM ALARMING LIMIT FOR DEPOSITS IN BOILERS ARE :-

UTILITY BOILERS : Should have deposits less than 1.5 g/m^2 of the tube area.

PRESSURE BOILERS : Should have deposits less than 4 g/m^2 of the tube area.

There are lot of users who often think the term "DESCALING" as a casual job and could be undertaken as Acid /Chemical Cleaning by any irrelevant manual. Descaling is a complete job, should be undertaken with proper descaling compound by experienced & trained companies. There are lot of small companies / vendors in the market who quote very cheap price to attract users and carry the job with countless damages which are not visible at the spot but hazardous and net loss in long run. Ultimately the users pay much higher price, sometimes substantial if something goes wrong.

It is always suggested to entrust the descaling job to an expert company having manufacturing facilities of above specified descaling compound suitable for different type of scales and metallurgy as well having experience in Water Treatment and Metal Treatment. This is required since the descaling job is interrelated with pre and post water treatment of concerned equipment.

THE USER SHOULD CHECK THE FOLLOWING LIST FROM THE DESCALER :-

1. Whether the compound is incorporated with Inhibitor, Scale Softener, Penetrator etc..
2. Static test of descaling compound on metal protection & dissolving of scale at laboratory level.
3. Inspection of equipment and submission of scale analysis report.
4. Past experience and trained personnel.
5. Evolution of technical expertise through detail discussion across the table.

WRONG SELECTION OF WATER TREATMENT CHEMICALS

Wrong selection of water treatment chemicals are useless rather it can be harmful for the system (boiler/cooling) and can cause following direct / indirect loss to your boiler /cooling system.

--- Loss of efficiency (Due to Scaling).
--- Unnecessary shut downs.
--- Accidents.
--- Loss of metal & alloys in your costly equipment (Due to Corrosion).
--- Algae growth in cooling tower (over feeding of phosphates).
--- Loss of production.
--- Loss of money (Cost of Chemicals).

Numerous combinations of chemicals have been recommended for treating cooling / heating water by various water treatment chemicals manufacturing companies. Some perform well, others are virtually useless while a few are harmful.

EXAMPLE :

OXYGEN SCAVENGER (FOR BOILER) :-

The chief factor of corrosion in boiler is oxygen. It is very necessary that it is completely removed in feed water itself. Formulation which include catalyst in Oxygen Scavenger remove oxygen fully due to fast reaction rate. Oxygen Scavenger without proper catalyst may not give you an indication of the harm it may have had on your boiler metal immediately but definitely will cost on the longer run.

FOR COOLING SYSTEM :-

Many companies are still using chromate in their formulation for prevention of corrosion in cooling system. Although chromate when used as Corrosion Inhibitor has done an outstanding job for years, but increasing concerns on environment have brought new inventions which gives better corrosion protection in alkaline system and has no- adverse environment impact.

Be sure about your present water treatment chemicals which should be safe for your equipment as well as environment around you.

DM WATER IS NOT ULTIMATE WATER FOR BOILER

Most of the Industrial users having DM plants feels that they don't require any Chemical Treatment at all for their boiler . It is our belief that when you are using De-mineralized water for your boiler that itself means that how much you care for you costly equipment. Following are reasons to suggest you that why you require chemical treatment even after using DM water.

1. DM water pH is low and hence to remove 'Co_2' completely from feed water itself, its pH needs to be raised to 8.2 min. Conventional alkali compound used to raise pH creates lot of complication so you require special pH booster, which doesn't do any harm to your system.

2. ISI code for boiler operation suggests to maintain phosphate residuals of 20-50 ppm in blow down water. This also ensures that during DM plant upset conditions like faulty regeneration, water quality fluctuation, resin fouling etc. calcium hardness going to boiler doesn't deposited. So Antiscalant treatment is must for the safe guard of your boiler.

3. DM plant doesn't remove any oxygen from the water even if you have installed de-aerator for removal of gases. It is not possible to remove oxygen completely by mechanical devices. Technically it is very essential to use oxygen scavenger to remove oxygen completely from fuel water itself to prevent corrosion in your boiler.

4. Whereas boiler water treatment chemicals are supposed to work inside the boiler. Condensate treatment chemicals are required to protect condensate line from corrosion. Alkalinity breaks downs into carbon-di-oxide, which evaporates alongwith steam and formation of carbonic acid bring down the pH of condensate (below 7) and resulted into corrosion of condensate lines, vapour phase Corrosion Inhibitors are must to protect your condensate lines.

HOW TO EVALUATE A NEW PROPOSAL OF WATER TREATMENT CHEMICALS FOR YOUR BOILER / COOLING SYSTEM

When contemplating a change in water treatment programme because of unsatisfactory results or when putting a new system in operation it is better to discuss the matter with representative of reliable, experienced and good company.

Usually only one programme is offered for controlling scaling, corrosion etc. This helps to sustain the myth that any water supply can be treated effectively by single chemical. When considering such proposals you should always insist on professional approach. After all you are legally responsible for the safety of your employees and also the harmful materials discharged to public water. The day is past when a chemical identified only by number or meaningless name was salvable. ***YOU MUST KNOW WHAT YOU ARE BUYING.***

Every cooling/heating system presents a unique combination of equipment, water parameters, blow down and control consideration. Proper selection of a sound water treatment programme requires collection of considerable amount of information.

After making a detailed survey of the system including its design, material of construction, current treatment a recommendation in form of proposal is made. Since monitoring a water treatment programme is key to success, the proposal must include method of control monitoring and follow-up. Corrective action are required for an effective cooling/ heating water treatment programme. The goal of monitoring is to identify potential problem before they occur.

MAXIMUM LIMITS FOR BOILER WATER

Specified by American Boiler Manufacturer Associations (ABMA) to assure good quality of steam.

Sr. No.	BOILER PRESSURE (PSIG)	TOTAL DISSOLVED SOLIDS (TDS) (PPM)	ALKALINITY (PPM)	SILICA (PPM)
1.	0 – 300	3500	700	125
2.	301 – 450	3000	600	90
3.	451 – 600	2500	500	50
4.	601 – 750	2000	400	35
5.	751 – 900	1500	300	20
6.	901 – 1000	1250	250	8
7.	1001 – 1500	1000	200	2.5
8.	1501 – 2000	750	150	1.0
9.	Above 2000	500	100	0.5

BLOW DOWN :- Boiler water 'blow down' is the removal of same of the concentrated water to be replaced by feed water. In this way the concentration of **TDS, ALKALINITY, SILICA** etc can be directly lowered to permissible limits. ***Continuous blow down*** for which boiler have arrangement is the most effective ***calculations for adjusting.***

FLOW RATE IN CONTINUOUS BLOW DOWN LINE OF A 450 PSI 20 T/HR. BOILER :

Feed water TDS - 50 (ppm) say

Upper limit TDS at 450 PSI - 2500 ppm (ABMA)

$$= \frac{50}{2500} \times 100 = 2\%$$

Steam Generation - 20 T/hr

Hence Blow down -

$$= \frac{20 \times 2}{100} = 0.4 \text{ Tons/ hr}$$

Best way of reducing % blow down is reducing **TDS, ALKALINITY, SILICA** etc in feed water itself by way of external treatment (i.e. DM Plant, etc) followed by internal treatment (chemical treatment).

"A SYSTEM DEMANDS SYSTEMATIC APPROACH "

WHY INSPITE OF REGULAR USE OF SCALE PREVENTIVE CHEMICALS YOU DON'T GET RESULTS ?

Every Cooling / Heating (boiler) water system presents a unique combination of equipment, water chemistry, contamination, blowdown and control consideration. A chemicals supplying company must take following details into consideration before supplying chemicals

--- THE SYSTEM DESIGN AND DATA.

--- RAW WATER CHEMISTRY

--- EXTERNAL TREATMENT / MAKE UP WATER CHEMISTRY

--- EFFLUENT CONSIDERATION

--- MATERIAL OF CONSTRUCTION

--- OPERATING TEMPERATURE

--- PRESENT TREATMENT

--- GEOGRAPHICAL LOCATION OF PLANT

--- SEASON OF YEAR

It is very difficult or impossible to maintain a system scale / corrosion free if any of the above points are not considered. Every system requires a different approach of treatment, which chemical is the best choice for a given system depends upon the specific conditions of that system.

CONTROL MONITORING AND FOLLOW UP

FIVE OUT OF TEN times a treatment fails because of lack of control monitoring and follow up. The goal of analysis and monitoring is to identify potential problems before they occur. Chemical control, monitoring of results, and corrective actions are a MUST for an any effective water treatment programme.

OBJECTIVE OF WATER TREATMENT is to maintain a scale / corrosion free system and to keep heat transfer tubes clean regardless of any mechanism and if a treatment fails inspite of retaining an experienced company on a continuous consulting basis then the objective of water treatment itself is defeated.

LOSSES DUE TO CORROSION IN STEAM AND CONDENSATE LINES

Corrosion of steam and condensate lines is one of the common problems being faced by facing plants. After boiler, corrosion may incur cost penalties such as :

(1) **REPAIR COST_**:- This depends upon the piping material used and local labour rates, such costs have been escalated and will continue to do so. Still the largest expense is not repairing the pipe ; it is the loss of production during repair.

(2) **STEAM LEAKS_**- These are oftenly overlooked in considering the cost of steam line corrosion. Usually , steam leaks are not serious enough to cause a boiler shutdown , but they do drain a system of valuable latent heat - Also increased fuel usage is needed to compensate for energy lost through the leaks.

(3) **CORROSION PRODUCTS** :- Return of corrosion products (i.e. Metal oxides) to the boiler water via the condensate have low solubility and therefore can deposit on boiler heat transfer surface due to their poor thermal conductivity these iron oxide deposits cause energy losses.

CAUSES OF CORROSION :-

There are two major causes of corrosion in steam and condensate line (1) **Oxygen** which results in pitting (B) **Low pH** which gives rise to generalized thinning of piping. Oxygen is found in the after boiler because (1) it is in the feed water and subsequently is flashed from the boiler with the steam. (2) It enters when air enters the after boiler section.

(B) Formation of low **pH** condensate is usually due to carbonic acid, when bi- carbonates breakdown in the boiler carbon-di-oxide thus produced to form carbonic acid in steam. In most cases, the bulk of carbon-di-oxide comes from the breakdown of feed water alkalinity.

CAUTION :- In the steam and condensate system, the combination of oxygen and carbon-di-oxide can be divesting, corrosion proceeds more rapidly in such a situation.

WHAT IS BOILER

WHAT IS A BOILER ?

A boiler is a vessel in which water is continuously vaporised into steam by application of heat. Boilers are generally of two types.

- **FIRE TUBE BOILERS.**

- **WATER TUBE BOILERS.**

FIRE TUBE BOILER :- In fire tube boilers , the flame and hot gases are confined within tubes arranged in a bundle within a water drum. Water circulates on the outside of these tubes. As the water changes to steam, it rises to the top of boiler drum and exits through a steam header. The fire tube boilers have a capacity restriction upto 20 kg/cm2 pressure because of design limitation.

WATER TUBE BOILER :- The water tube boiler differs from the fire tube boiler in that the flame and hot combustion gases flow across the outside of tubes and water is circulated within the tubes. Combustion of fuel occurs in a furnace and some of the water tubes usually form the furnace walls . In a simple water tube circuit steam bubbles form on heated side of tubes. The resulting steam water mixture has a density below that of cooler water on the unheated side and rise, creating a circulation through the system. The steam bubbles rise until they reach the steam drum where steam is released from the water into vapour space.

WHAT IS A LOW/MEDIUM/HIGH/PRESSURE BOILER ?

Generally boilers working upto a pressure of 250 PSI are classified as low pressure boilers. 250-900 PSI as medium pressure and above 900 PSI as high pressure boilers. Working pressure of a boiler is either expressed in PSI or kg /cm^2 (1kg /cm^2 = 14.5 PSI approx.)

HOW WATER AFFECTS THE PERFORMANCE ,LIFE AND SAFETY OF BOILER ?

The chemical and physical developments within the boiler are influenced by the composition of the boiler water. Basic understanding of water treatment process and water chemistry is essential for maintaining efficient operation of boiler . In order to avoid three major problems in the boiler system i.e. Scale, Corrosion & carryover following factors are to be kept in mind.

- Pressure and design of boiler.

- Concentration of the contaminants found in water supply.

WHAT ARE THE OBJECTIVES IN TREATING WATER FOR BOILERS

- **PREVENTION OF SCALING IN BOILER.**
- **PREVENTION OF CORROSION IN BOILER.**
- **PREVENTION OF STRESS CORROSION CRACKING.**
- **PREVENTION OF STEAM CONTAMINATION.**

WHAT PHYSICAL METHODS ARE USED FOR IMPROVING WATER QUALITY ?

Main physical methods for improving quality of water for boiler are.

- Clarification.
- Deaeration.
- Oil Removal.
- Blow down.

WHAT IS AN EXTERNAL TREATMENT ?

Treatments of water that are done outside of the boiler are called pre- boiler or external treatment. When preparing water for boilers operated at less than 150 PSI, all necessary chemical treatments can be accomplished in a classifier, but as pressure increases; the quality of feed water must improve. The purpose of external treatment is to

- Reduce suspended solids
- Softening water.
- Removal of silica.

THIS PURPOSE CAN BE ACHIEVED BY

- Coagulation by chemicals.
- Softening (Cold lime, Soda process, Hot lime-Soda process, Cation, exchange)
- Silica removal- (Coagulation with chemical, Demineralization)

WHAT IS AN INTERNAL TREATMENT ?

There are number of treatments that are made within the boiler to minimize the adverse effects of small concentration of components that remain in the feed water after the external treatment. Inspite of various external treatment it is not possible to attain an absolute perfect quality of boiler feed water. Chemical treatment or internal treatment of water inside the boiler is essential to take care of various impurities entering into the boiler such as Hardness, Oxygen, Silica.

CAN INTERNAL TREATMENT ALONE CAN WORK IN A BOILER ?

In many cases external treatment of water supply is not necessary specifically in low or moderate pressure boilers or where large amount of condensed streams are used or when raw water available is of very good quality.

"WISH FOR A SMOOTH FUNCTIONING OF YOUR BOILER"

Boiler engineer must know important properties in boiler water chemicals & its treatment :-

HARDNESS :- Hardness is perhaps the most troublesome of all water impurities. It may cause scale formation in boiler, hardness accures is due to soluble compounds of calcium and magnesium in the form of calcium carbonate and magnesium carbonate.

WHY pH CONTROL IS REQUIRED IN A BOILER :-

Low pH causes corrosion, the pH of boiler water is very important control parameter for protecting boilers against corrosion. The first step in corrosion is iron dissolving in water. This reaction gets suppressed as the pH value of water increases.

WHY FEED WATER pH IS NOT KEPT LESS THAN 8.5 IN A BOILER ?

In order to prevent corrosion of feed pimp, piping and economiser, the feed water pH must be maintained at not less than 8.5.

WHAT pH VALUE IS IDEAL FOR BOILER WATER ?

In a boiler water it is recommended to operate at a pH 10.2 to 11.2 to prevent acidic corrosion. A good control point is 10.6.

CONTROL OF TOTAL DESSOLVED SOLIDS

When raw water from its source is high in its TDS contents, it is desirable to remove it in pretreatment preferably since boiler water concentrate by 8 – 10 times even normal blowdown are maintained. When TDS cross the prescribed limit for a boiler, it should be controlled by blowdown if necessary more than a shift as boiler water blowdown is the only direct method of lowering concentration of solids.

WHAT IS CAUSTIC ALKALINITY ?

This is the alkalinity due to free hydro-oxide in water (OH) ions. It is essential to maintain caustic alkalinity in boiler water to achieve following objectives.

- To maintain protective coating of ironoxide over the boiler metal and thus prevents corrosion.
- To keep silica in solution and thus avoid deposition of hard scales or vitalisation along with steam.
- To promote precipitation of any magnesium hardness which enters along with feed water. However high alkalinity can cause foaming or caustic embrittlement under certain conditions.

BOILER FEED WATER TREATMENT- A REVIEW (PART-I)

Even though boiler feed water treatment is an important and very well known subject, it is one of the most neglected subjects by the working factories. Break downs are many and break downs have become a normal way of operating the boilers. Boiler tubes are renewed within three years of installation whereas these are supposed to last for a minimum of fifteen years. In most of our factories, the boiler installations are quite modern and the design features are uptodate except in a very few cases. The boiler break downs therefore, are mainly due to defective operative operations only. The boiler feed water which lacks adequate attention from the Chemists and Engineers is the root cause for most of the ills in our boiler installations. Periodical reviews are, therefore, necessary to refresh our memories and update our knowledge. The sources of water available for the boilers, the deficiencies of these waters and the treatments that are required to make them safe for taking into the boilers have all been discussed in brief in this review.

WHAT ARE THE SOURCES OF WATER THAT ARE AVAILABLE FOR USE AS BOILER FEED ? WHAT ARE THEIR DEFICIENCIES ?

1. RAIN WATER :- Even though this is the purest form of natural water, this absorbs carbon-di-oxide, oxygen, dust and smoke during its passage from the upper stage of atmosphere to the earth. The rain Water is, therefore, unfit for the use as boiler feed.

2. RIVER WATER :- This contains dissolved gases like CO_2 and Oxygen, salts of Ca, Mg & Na in addition to suspended organic matter and as such is also unfit for use as boiler feed.

3. LAKE OR POND WATER :- This is almost like the rain water and so is unfit.

4. WELL WATER :- Even though suspended organic matters are absent, this water contains almost all the ingredients that are found in the river water or pond water.

5. CONDENSATE WATER :- Condensate water is possibly only purest form of water almost like distilled water, is available for requirement and it is for the technocrats to utilize this water properly as boiler feed after proper treatment wherever necessary.

BOILER FEED WATER TREATMENT - A REVIEW (PART-II)

WHAT ARE THE AFTER EFFECT AS WHEN FEED WATER IS NOT ATTENDED TO PROPERLY ?

I. Scale Formation
II. Corrosion
III. Priming and Foaming
IV. Caustic embrittlement

I . SCALE FORMATION :- Scale formation is due to hardness of water.

There are two types of hardness.

1. Temporary Hardness (Carbonate Hardness)

2. Permanent Hardness (Non Carbonate Hardness)

Temporary Hardness is caused by Bicarbonate of Calcium and Magnesium (Ca & Mg). In the boiler drums at high temperatures, the bicarbonates break down to form carbonates and hydroxide scales :

$$MgCO_3 + H_2O \longrightarrow Mg(OH)_2 \downarrow + CO_2 \uparrow$$

The scales are porous and soft sludges.

Temporary hardness can be removed by flushing out the sludges with frequent or continuous blow downs. Use of polymeric sludge conditioners will help in fluiduising the sludge which can be easily removed by blow down.

Chlorides, Sulphates and Nitrates of Calcium and Magnesium are responsible for causing permanent hardness. They deposit as scales on the boiler drums and boiler tubes. Permanent hardness be dealt with by avoiding their formation by taking appropriate action as detailed later.

WHAT ARE THE EFFECTS OF SCALE FORMATION ?

(a) **HEAT TRANSFER IS INHIBITED :-** It has been found that a scale equal in thickness to that of the boiler drum metal retards the conductivity of heat by 20 times. There is, therefore, loss of heat energy and the subsequent inefficiency in steam generation.

(b) **BURSTING OF BOILER TUBES :-** In the boilers tubes, these scales form pockets which get overheated and cause bursting of these tubes.

(c) **TURBINES ARE AFFECTED :-** These scales, when carried over by steam, get deposited on the turbine blades and cause sluggishness in the working of turbines. When the deposits are heavy, even explosion of the turbines occur.

Note : Formation of scales should be avoided at all costs.

BOILER FEED WATER TREATMENT – A REVIEW (PART-III)

WHAT ARE THE FACTORS RESPONSIBLE FOR CORROSION OF THE FEED WATER LINES, BOILER TUBES, DRUMS AND CONDENSATE LINES ?

(a) Dissolved Oxygen in the feed water will cause 'Pitting' corrosion in the feed water lines, boiler tubes, drums, steam lines, turbines and return condensate lines.

(b) Carbon-di-oxide present in the feed water normally does not affect the feed lines and boiler tubes. But CO_2 affects the return condensate lines. CO_2 goes along with steam from the boiler and whenever steam condenses CO_2 dissolves in the condensate forming Carbonic acid which attacks the metal. 'Grooving' type of corrosion is normally formed due to Carbonic acid attack.

(c) Hydrochloric Acid, Nitric Acid and Sulphuric Acid are formed when Chlorides, Nitrates and Sulphites of Calcium and Magnesium are hydrolysed by the water in the boiler and they corrode the drums and tubes.

HOW CAN WE REMOVE O_2 AND CO_2 FROM BOILER FEED WATER ?

Deaeration by the use of mechanical deaerators is widely used to remove dissolved gases from water and thereby control corrosion. In particular it is used to remove oxygen from boiler feed water systems.

Boiler feed water is dearated by spraying the water into a steam atmosphere. This heats the water to within a few degrees of the temperature of the saturated steam. Since the solubility of O_2 in water is very low under these conditions, 97-98% of the O_2 in the incoming water is released to the steam and is removed from the system by venting. The remaining O_2 is not soluble under equilibrium conditions but is not readily released to the steam. Water leaving the heating section of the deaerator must therefore be vigorously scrubbed with steam to remove the last traces of O_2. Deaeration by this method will reduce dissolved O_2 to as low as 0.005 cc/litre. **FOR COMPLETE O_2 REMOVAL** mechanical deaeration requires **CHEMICAL ASSISTANCE**. When mechanical deaeration is not available, chemical deaeration alone will be adequate, but not all operating conditions. For most systems it would be economical to combine both mechanical and chemical deaeration.

For boilers operating below 100 Psi, addition of Catalysed Sodium Sulphite will help in instantaneous removal of O_2 from the feed water. It is desirable to use catalysed Sodium Sulphite instead of ordinary Sodium Sulphite as the reaction rate of catalysed Sodium Sulphite is 80-100 times faster than that of ordinary Sodium Sulphite.

HOW DO WE PREVENT CORROSION IN THE RETURN CONDENSATE LINES ?

Corrosion in the return condensate lines due to O_2 is taken care of by deaeration both by chemical and mechanical means as explained above. Carbonic Acid attack in the return condensate lines is prevented by the use of neutralizing amines. (For more detail on return condensate please read our Technical Bulletin No. - 366.)

BOILER FEED WATER TREATMENT – A REVIEW (PART-IV)

WHAT IS MEANT BY CARRY OVER ?

When priming and foaming occur in the boiler drum, steams carry with water droplets containing suspended and dissolved matter to the turnines. This is known as carryover.

WHAT IS THE ILL-EFFECT OF CARRY OVER ?

Suspended and dissolved solids get deposited on the turbine blades with the resultant bad effects that have already been narrated under the heading scales. So, priming and foaming with the resultant carry over should totally be avoided.

HOW DO YOU PREVENT CARRY OVER ?

Carry over can be controlled through careful boiler operation. Maintenance of proper steam drum water level can help prevent foaming and priming. Blowing down as recommended will remove excessive amounts of dissolved and suspended solids, aiding in the prevention of foaming and spray carry over.

A good water treatment programme is also important for controlling carry over. Internal boiler water treatment removes contaminants which cause carry over. Special treatment products known as antifoams have been found useful in preventing this problem. These are usually polymerised either and amines. They are believed to cause boiler water bubbles to flow together into larger irregular shapes which are more easily broken at the surface, thereby decreasing foaming and spray carry over. Use of sludge conditioners also helps in preventing carry over besides preventing deposits.

In summary the following steps may be taken to prevent carry over :

1. Maintain the Total Dissolved Solids at less than 1500 mg/litre by monitoring the blow down.

2. Avoid using raw water for make up purposes. Use only demineralised water.

3. Continuous blow down from the steam drum is preferable to control TDS. Intermittent blow down from the mud drum will help in removing the accumulated sludge.

4. Use proper internal water treatment chemicals.

5. Use of sludge conditioner and antifoaming will greatly help in reducing carry over.

6. Water levels in the steam drum should be maintained only at the specified level.

7. It may be desirable to install mechanical separators in the steam line before the turbine. One or two separators can be installed and these will help in trapping water and it's impurities in the event of any carryover. This will be an addition protection to the turbine against carryover deposits.

BOILER FEED WATER TREATMENT – A REVIEW (PART-V)

WHAT ARE THE TOLERABLE LIMITS FOR THE CONSTITUENTS OF BOILER FEED WATER ?

We give blow the IS Standard for feed water and boiler water limits :-

IS Standard (10392 - 1982)

CHEMICAL REQUIREMENT FOR FEED WATER AND BOILER WATER FOR LOW AND MEDIUM PRESSURE BOILERS.

No. Particulars	Requirement for Boiler Pressure			Method of Test	
	Upto 20 kg/cm^2	21 to 39 kg/cm^2	40 to 59 kg/cm^2	IS35550 1965*	IS3025 1964 +
1	2	3	4	5	6
FEED WATER					
* Total Hardness (as $CaCO_3$) mg/L (Max.)	10	1.0	0.5	--	16.1
* pH Value	8.5 - 9.5	8.5 - 9.5	8.5 – 9.5	--	8.0
* Dissolved Oxygen (mg/L)	0.1	0.02	0.01	25	--
* Silica (As SiO_2)	--	5	0.5	16	--

1	2	3	4	5	6
BOILER WATER					
* Total Hardness (of filtered Sample as $CaCO_3$) as mg/L (Max.)	--	Not Detectable	--	--	16.1
* Total Alkalinity (As $CaCO_3$) mg/L (Max.)	700	500	300	--	13
* Caustic Alkalinity (As $CaCO_3$) mg/L (Max.)	350	200	60	--	15
* pH Value	11.0 – 12.0	11.0 – 12.0	10.5 – 11.0	--	8.0
BOILER WATER					
* Residual Sodium Sulphite (As Na_2SO_3) mg/L	30 – 50	20 – 30	--	--	21
* Residual Hydrazine (As N_2H_4) mg/L	0.1 – 1.0 (if added)	0.1 – 0.5 (if added)	0.05 – 0.3	26	--
* Ratio Na_2SO_4 Caustic Alkalinity (as NaOH) or Ratio $NaNO_3$ Total Alkalinity as NaOH	--	Above 2.5	--	--	20.2 & 15
* Phosphates (PO_4) mg/L (if added)	20 – 40	15 – 30	5 – 20	14	--
* Total Dissolved Solids mg/L (Max.)	3500	2500	1500	9	12
* Silica (as SiO_2) mg/L (Max)	Less than 0.4 of Caustic Alkalinity	15	16	30	--

NOTE-1 : Recovery Boilers - The boiler feed water used should be completely demineralised and also the boiler feed water and boiler water should be conditioned in accordance with high pressure boilers working at 60 kg/cm^2 and above (ooo IS : 4343 - 1967) **

NOTE-2 : When feed water heaters are of copper or copper alloy contructions, the pH of the feed water should be maintained between 8.5 and 9.2 while when feed water heaters are of iron construction, the pH of the feed may be maintained between 8.5 and 9.5.

NOTE-3 : Silica in boiler water - lower concentration of silica may be advisable for steam of turbines which generally requires less than 0.02 mg/ltr. silica in steam.

WHAT ARE THE SOURCES OF BOILER FEED WATER IN A SUGAR FACTORY

i) While starting the factory : Raw water from wells and rivers.

ii) After starting the factory : Condensate from evaporators and pans.

CAN WE TAKE RAW WATER INTO THE BOILER ?

Raw water **SHOULD NOT** be taken into the Boiler. Use of raw water will give rise to scaling and carry over in the boiler. Only treated water should be used for make up purposes. It is preferable to use demineralised water for the same. However for low pressure boilers softened water may also be used. In either case, while installing the treatment plant, care should be taken to see that adequate capacity is provided. Also adequate storage capacity for the treated water should be planned.

WHAT DO YOU KNOW IN SOFTENING & DEMINERALISATION OF WATER ?

The raw water containing hardness causing salts is softened by exchanging such salts to soluble sodium salt.

eg. : The softening process in described chemically as follows :

$$CaCl_2 + R.Na = R.Ca + 2\,NaCl$$
$$MgSO_4 + R.Na = R.Mg. + Na_2SO_4$$

WHAT IS MEANT BY DEMINERALISATION ?

Removal of all the ions (cations and Anions) present in raw water is called Demineralisation. Demineralisation is a two step process accomplished by sequential cation and anion exchange.

eq. :

Cation Units :-

$$RH + CaCl_2 = RCa + HCl$$

Anion Units :-

$$ROH + HCl = RCl + HOH\ (H_2O)$$

Where R is the Resin, H and OH represents Hydrogen and Hydroxyl.

NOTE :-

To get ultra pure water, Mixed Bed can be installed after the two bed demineraliser.

Q. Do we need storage for softened/demineralised/condensate water ?

A. Yes, we need. About six hours, steam generating capacity.

Q. If we take pure condensate from heat exchangers, do we need internal chemical treatment ?

A. Internal chemical treatment is required as there are impurities even pure condensates.

The impurities are mainly O_2, CO_3, NH_3, Organic acids and like acetic acid, Aldehydes, which depend upon the quality of cane crushed and also SO_2 coming along with clear juice.

A certain pH in the feed/boiler water to be maintained. The main reason for pH control evidently steam from the fact that ingress of SO_2 and other gases used for bleaching causes sudden drop in alkalinity of feed water and boiler water.

Alkalinity is necessary for the following reasons :

a) To convert magnesium to magnesium hydroxide sludge which is easily removed by blow down. If magnesium is allowed to react with phosphate, magnesium phosphate, a thick slimy sludge will be formed which is as bad as a scale. Therefore, OH alkalinity is provided whereby magnesium preferentially reacts with it to form magnesium hydroxide.

b) To minimize solubility of iron by maintaining a coating of iron oxide over boiler metal.

c) It keeps silica in solution, i.e. It reacts with silica and forms a complex silicate compound which will remain in solution and will not precipitate.

d) Excess alkalinity should be avoided as it will give raise to caustic embrittlement.

CAUSTIC EMBRATTLEMENT

WHAT IS MEANT BY CAUSTIC EMBRATTLEMENT AND CAUSTIC GOUGING ?

Caustic embrattlement (Inter granular corrosion) in boilers is a form of strong corrosion cracking. It is caused by the high concentration of caustic alkalinity in crevices under over stressed conditions. Leaking rivets and lap-seam joints provide areas of stress and caustic concentration.

Caustic gouging is the accumulation of caustic alkalinity under the deposits in the boiler. This can occur even if there are no rivats and crevices.

HOW DO YOU PREVENT CAUSTIC EMBRATTLEMENT AND CAUSTIC GOUGING ?

In welded boiler caustic embrattlement does not occur. However in riveted boilers caustic embattlement can be minimised by using an effective inhibitor. Sodium Nitrate is an effective inhibitor when maintained in boiler water at concentration equal to 20-30% of sodium Hydroxide alkalinity.

Caustic gouging can be prevented by ensuring that there are no deposits in the boiler. Use of sludge conditioners will prevent deposits and thereby caustic gouging. Inhibitors like Sodium Nitrate may also be used for preventing caustic gouging.

DO IDLE BOILERS (i.e. WHEN BOILERS ARE NOT IN USE) REQUIRE PROTECTION AGAINST CORROSION ?

Yes, idle boilers requires protection, otherwise they can corrode badly. It has been found that with improved cleanliness of boiler surfaces the metal is prone to oxygen attack giving rise to pitting corrosion. Boilers which are idle for even such short time periods as weekends are susceptible to attack. Therefore it is necessary to protect the boiler against corrosion by employing suitable storage methods. When the boiler is not in use it should be cleaned if necessary and filled to the normal water level with deaerated feed water. By addition of chemicals a minimum of 400 ppm of 'P' Alkalinity and 100 ppm of Sulphite is preferable. Alternatively catalysed Hydrazine and neutralising amine may be added to maintain 200 ppm of hydrazine and a pH of 10 in the boiler water. After the chemicals are added the water should be circulated for thorough mixing. The boiler water should be tested regularly at least once a week with treatment bening added as necessary to maintain minimum treatment levels. This will prevent corrosion when boilers are not in use.

SUPER HEATER AND TURBINE DEPOSITS - IN BOILER

Foaming and carryover of boiler water results in the formation of salt deposits in super heater tubes and on turbine blades. Factors that can cause this sort of fouling are :-

- Too high a rate of firing .
- High steam release velocity.
- Sudden radical changes in steam rate.
- Mechanical carryover.
- Chemical conditions – such as high alkalinity or high TDS.
- Contamination of boiler water by saponificable oil.
- Presence of finely divided suspended solids such as oxides of iron and copper arising from corrosion in condensate and pre boiler system.

In addition to operational and chemical deficiencies, there are number of mechanical malfunctions - often over looked - that allow boiler water to contaminate steam.

WHAT CAN BE DONE TO PREVENT MECHANICAL CARRYOVER ?

- The primary steam separators should be kept clean - because small deposits of rust or salts produce high velocity through the screen driers that that results in carryover of boiler water.
- Separator cartridges must be bolted tightly so there are no cracks or other openings.
- Hand hole covers in steam chest must be securely closed and drains must be open.
- The feed water inlet is usually behind the steam separation baffles with feed water being distributed over the length of steam drum through curved tubes. If any of these inlet tubes are missing, or leak at the union, feed water is thrown into steam chest.
- Care must be taken to maintains the proper water level, because if it is so low that the outlets of the steam generating tubes in the convection section are below the surface, water is thrown across the drum into the primary steam separator.

NOTE :- SCOPE OF THIS BULLETIN IS TO HIGHLIGHT COMPLICATIONS IN OPERATION OF BOILER AND TO IMPROVE THE BOILER EFFICIENCY AND STEAM QUALITY. ALBATROSS CAN ONLY HELP IN SOLVING WATER RELATED PROBLEMS THROUGH CHEMICAL TREATMENT.

BOILER PREVENTIVE MAINTENANCE (PART-I)

A major responsibility of the operator is to keep the boilers in good operating condition. The primary concern in the operation of steam boilers, regardless of pressure or type, is safety. Like any pressure vessel, boilers represent potential risks to personnel and property. Good operating practices result in the maximum reliability and efficiency.

Employ only trained, qualified operators.
Provide a continuing operator training program.
Institute and maintain a boiler water treatment program under the supervision of personnel trained in this field.

TRAINED OPERATORS

One of the best way to extend the useful service life of a boiler is to use qualified and highly trained operators. Just as a car should not be operated by an in-experienced driver, a boiler should not be operated by an untrained or unqualified operator. The boiler investment far exceeds the cost of a car and demands even more respect.

In all installations, the operator should study the operating and maintenance instructions provided by the manufacturer covering the automatic and manual operation of the boiler. The operator must be familiar with how the boiler functions and the purpose of all controls. Written instructions should be provided to take care of emergencies. The operator must know how to periodically test all controls.

PERIODIC RETRAINING :

Establish a continuous training program for operators. After experienced operator observes an automatically fired boiler for several months without any emergencies developing , the operator might be inclined to forget what action is included under certain conditions. Refresher training in emergency operations can pay high dividends when emergencies occur.

BOILER WATER TREATMENT

Modern boilers have a high heat-absorption rate, so internal surface must be free from scale and sludge. The treatment of boiler water is a specialized field and requires the services of trained personnel. An individual or organization specializing in feed water treatment can recommend the type of treatment required to keep the surface clean, minimize the amount of blowdown and prevent corrosion. A clean boiler will operate more economically and enjoy a longer service life.

BOILER PREVENTIVE MAINTENANCE (PART-II)

PM PROGRAM

Every boiler plant needs a PM program. Programs vary according to the types of boilers being used, as well as the conditions under which they are used. Some boilers require monthly cleaning, while others require semi-annual cleaning.

It is difficult to establish a maintenance program that would cover all conditions for all boilers. A checklist for proper boiler maintenance, however, should be similar to the following but will vary depending on the type of boiler and service:

DAILY

Give the boiler measured bottom blowdown according to instructions provided by the company supplying the feed water treatment.

Remove accumulations on water surface by using surface blowdown valves.

Blowdown the water column.

Test low-water cutoff and feed water regulator.

Operate safety valves manually on start up.

Check lubrucation on auxiliary equipment.

When starting the boiler, make sure the ignition operates properly.

Keep the boiler room clean.

QUARTERLY

Examine the water sides of the boiler.

Examine the heating surface for corrosion, pitting and scale.

Install new handhole and manhole gaskets when closing up the boiler.

Examine all valves and cocks for freedom of action and leaks.

Refill the boiler to the proper water level and add required chemical treatment.

SEMIANNUALLY

Clean the fired surfaces of the boiler.

For firetube boilers, brush out the tubes with al flue brush.

For package boilers, examine and renew, if needed, the seal between rear cover brick and brick frame or the baffle.

ANNUALLY

Clean the fire and water sides thoroughly.

Check all refractory equipment.

Plan to overhaul auxiliaries.

Check the electrical controls and terminals.

Dismantle and clean low-water cutoff and feedwater regulator, or have this performed by a qualified service organization.

Proper maintenance assures that your boilers will work at maximum efficiency throughout the year. PM, as distinguished from actual repairs, includes four major elements:

Planned shutdown schedules.

Periodic inspections by skilled personnel.

Inventory and inspection records.

An adequate stock of replacement parts on hand or available from supplier.

A well-recognized and planned maintenance program can reduce repair expenses by 25 percent.

CONDENSATE (PART-I)

WHAT IS CONDENSATE ?

Condensate is steam that has condensed as a result of doing work and giving up heat. Examples of doing work include driving turbines, heating buildings and processes.

WHY IS CONDENSATE IMPORTANT AND HOW CAN IT IMPROVE BOILER OPERATION ?

Condensate is very high in heat content A pound of 180 ^{0}F condensate contains 148 BTUs Bringing this condensate back to the boiler reduces the amount of fuel necessary to convert a pound of feed water to a pound of steam. The net result is reduced fuel consumption.

Returned condensate is a readily available economic feed water source. Since properly treated condensate is very pure, returning condensate to the feed water will improve feed water quality and reduce makeup water demand. Pretreatment costs will also be reduced. Better feed water quality also means more reliable boiler operation.

Since condensate is low in dissolved solids increasing the amount of returned condensate allows a boiler to operate at a higher cycle of concentration thus reducing the volume of blowdown. Reducing the volume of blowdown will reduce the amount of heat loss from the boiler system through blowdown and will lower fuel expenditures.

CONDENSATE CORROSION AND ITS EFFECTS :-

Corrosion in condensate systems can limit its quality or quality of returned condensate because of iron and copper products. Which can deposit on boiler heat transfer surface. This reduces heat transfer efficiency and could cause tube failure. Condensate corrosion control is required to protect process equipments and tanks as well to maintain the condensate as a quality feed water source. Corrosion of the condensate system can result in increased maintenance and equipment replacement costs. Energy loss through leaks and loss of process heat transfer efficiency (Ref. For more detail our T. B. – 370)

LOSSES DUE TO CONDENSATE CORROSION

Increase in fuel consumption

Iron deposit thickness	0.5 mm	1 mm	2 mm
Loss in efficiency	3%	6%	9%

Max. Iron content permissible in condensate :-

BOILER PRESSURE	**PERMISSIBLE LIMIT**
0 – 300 PSI	0.10 ppm
301 – 450 PSI	0.05 ppm
451 – 600 PSI	0.03 ppm

CONDENSATE (PART – II)

THE CAUSES OF CONDENSATE SYSTEM CORROSION

Condensate corrosion is caused by gases in the steam that dissolve in condensate to form a corrosive solution. Common gases found in condensate system are :-

1. Oxygen - Most corrosive to ferrous metals, copper and copper alloys.
2. Carbon-di-oxide - Most corrosive to ferrous metal.
3. Ammonia - Most corrosive to copper alloys.

Presence of gases together accelerates corrosion rate by 10 – 40 times faster than either gas alone.

WHAT ARE THE SOURCES OF THESE GASES ?

1. SOURCE OF CARBON-DI-OXIDE :-

The major source of carbon-di-oxide in steam is breakdown of feed water bi-carbonate and carbonate alkalinity in the boiler. At boiler temperatures and pressure the following reaction occur :-

$$\text{(i)} \quad 2NaHCo_3 \xrightarrow{\text{Heat}} Na_2Co_3 + Co_2$$

$$\text{(ii)} \quad Na_2Co_3 + H_2O \xrightarrow{\text{Heat}} 2NaOH + Co_2$$

The first reaction proceeds 100% to completion. The second proceeds to approx. 80% completion. The liberated Co_2 is carried with the steam into the condensate system. ***<u>It is to always kept in mind that high feed water alkalinity will produce extremely corrosive condensate.</u>***

NOW CARBON-DI-OXIDE IS NOT HARMFUL UNTIL IT DISSOLVES IN CONDENSATE AND LATER FORMS CARBONIC ACID.

$$Co_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

Since condensate is extremely pure. Even small quantity of carbonic acid can significantly lower condensate pH and increases its corrosivity. Since condensate is hot this causes condensate to be even more aggressive to metal surfaces.

2. SOURCE OF OXYGEN :

Oxygen is present in most make up waters but is usually removed prior to entering the boiler by mechanical and chemical means. In case oxygen is not removed then it will flash with the steam

PROBLEMS CAUSED BY MICROBIAL FOULING OF COOLING TOWERS

1.	Algal growth in cooling tower slats	♦ Causes uneven flow distribution ♦ Unsightly ♦ Potential addition of nutrients to Water
2.	Biofilms on pipes and pumps	♦ Reduced flow rate ♦ Increases turbulence ♦ Increases pumping energy required
3.	Biofilm on distribution troughs	♦ Causes uneven distribution of water
4.	Detached biofilm	♦ Blockage of pipes/pumps/filters
5.	Biofilms on heat exchangers	♦ Acts as insulators ♦ Decreases heat transfer efficiency ♦ Prevents access of corrosion inhibitors
6.	Microbial induced corrosion	♦ Corrosion of bare metal by bacteria and fungi in the biofilm.
7.	Fungal growth	♦ Blocks pipes / filters ♦ deterioration of cooling tower timber
8.	Degradation of water treatment	♦ Loss of properties by additives corrosion inhibitors and descaling agents
9.	Health hazards	♦ Legionella spp.

What are the ECONOMIC LOSSES CAUSED BY BIOFOULING OF HEAT EXCHANGERS?

1. Cost provision of extra heat – exchanger surface in new plant to allow for fouling
2. Extra maintenance required for cleaning process surfaces(blocked pipes/pumps etc)
3. Loss in production as a result of increased down time
4. Reduced flow/increased turbulence results in requirement for increased pumping pressure
5. Microbial induced corrosion of unprotected metal surfaces
6. Deterioration in cooling tower timber.

What are the PROBLEMS IN COOLING TOWER SYSTEMS ?

Growth of algae primarily occurs in the tower deck area because of ample sunlight; algae require sunlight to grow, and many types contain the green pigment chlorophyll, which traps the energy from sunlight. Algae are generally introduced from the atmosphere as spores. They readily become established in areas where there is plenty of sunlight, such as the top of the deck and at the sides of the tower. On the other hand, they may be introduced in the makeup water, if it is untreated river or lake water.

Define OXIDIZING BIOCIDES

Chlorine initially dissolves in water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl).

$Cl_2 + H_2O = HOCl + HCl$

The production of acids leads to a drop in the pH of the water. The oxidizing biocides can react with many minerals, such as ferrous iron, as well as organic matter, producing precipitates of iron oxide and organic matter. The reaction with organic matter is much slower than with inorganic ions. This explains why the chlorine demand of waters containing organic acids (e.g., humic and fulvic acids) gradually increases over time. Chlorine, supplied as a liquid in pressurized cylinders or as a 10-15% solution in water (sodium hypochlorite NaOCl) stabilized with sodium hydroxide, is now the most commonly used oxidizing biocide.

When chlorine is added from cylinders, it forms a gas that combines with water to form hypochlorous and hydrochloric acids. This is an equilibrium reaction, which means that chlorine gas may be formed by the addition of excess HCl. The formation of Cl_2 generally occurs at pH levels below 4.0.

At pH levels around neutral, chlorine is present mainly as HOCl; and as the pH increases, the proportion of HOCl to Cl_2 increases. At pH values above 7.0, HOCl dissociates as follows:

$HOCl = OCl^- + H^+$

This is also an equilibrium reaction; it may be forced to be left to produce more HOCl by adding excess H^+ ions (in the form of acid), which will also decrease the pH. At pH 4.0 most of the chlorine is present as HOCl, whereas at pH 10.0 most of the chlorine is present as OCl^- ions.

At pH values above 7.0 most of the biocidal activity of chlorine is provided by the HOCl molecule. The hypochlorite ion evidences little biocidal activity; it acts more as a biostat in high pH waters. This explains why chlorine is much less effective at pH values above 8.0 in cooling systems. On the other hand pH is maintained above 8 in modern alkaline treatment approach.

Chlorine may also be supplied in convenient forms such as sodium hypochlorite (a 10-15% solution of NaOCl in water) and calcium hypochlorite [a solid containing 70% $Ca(OCl)_2$].

It should be kept in mind that the addition of hypochlorites may increase the pH of the cooling water (due to the formation of NaOH), whereas the addition of chlorine gas may reduce the pH (due to the formation of HCl).

What are the DISADVANTAGES OF CHLORINE TREATMENT ?

CHLORINE

Although Chlorine is most widely used in industry and it's a very powerful oxidizing agent that combines readily with protoplasm, forming stable Nitrogen-Chlorine bonds with protein-bound nitrogen. It is therefore, toxic to all living organisms. Although it leaves the cell walls intact, it causes serious damage within the cell. However, the activity of chlorine is decreased by certain types of organic matter including masses of algae or slime. Chlorine treatment has several disadvantages that should be considered.

- Difficult and dangerous to handle.
- Extremely corrosive to many metals.
- Maintenance of chlorinator and piping is costly.
- Due to its reaction, with number of contaminants common in cooling tower, it lowers the pH of circulating water.
- Considerable Chlorine is dissipated from the warm water as it rains down through tower, often reducing its concentration in basin to negligible value.
- Chlorine also reacts with number of treatment chemicals like antiscalant and dispersants, interfering with their function and being itself inactivated as biocide.
- Chlorine by solubilizing with extractives of wood of tower becomes susceptible to attack by fungi thus reduces the life of tower itself.

HALOGEN-RELEASE BIOCIDES

The halogen-release biocides are organic biocides that release chlorine and/or bromine in contact with water. These products are solid forms of halogens, and they have the advantage of added stability. They have particular advantages, because the addition of chlorine and bromine means that lower residuals are generally effective (bromine being more effective at high pH than chlorine).

HYDROGEN PEROXIDE (H_2O_2)

H_2O_2 is a very strong oxidizing agent and an effective biocide at very low levels over a wide pH range. The product actively generates oxygen from solution when reacted with certain organic matter. H_2O_2 is generally not used for the treatment of cooling waters because of its high cost and reactivity. It reacts with most materials in cooling systems (such as wood and metals), so that very little residual is left in large systems.

NONOXIDIZING BIOCIDES

Nonoxidizing biocides are organic molecules that react with various parts of the microbial cell, generally at a specific site. They do not oxidize cell components. The most common groups of nonoxidizing biocides are aldehydes, organo-sulfur biocides, organo-nitrogen biocides, amine salts, and heavy metals.

ALDEHYDES

The most common forms of these biocides are formaldehyde and glutaraldehyde. Formaldehyde is generally not used in cooling systems, because many bacterial species readily adapt to its presence (some bacteria grow well in the presence of up to 3000 ppm of formaldehyde) as well as using it as a source of carbon for cell growth. This is the reason it is used as a preservative at high levels (10%). Glutaraldehyde, a much more effective biocide than formaldehyde, can be used effectively in small systems. It is especially effective against sulfate-reducing bacteria and algae, but less effective against aerobic bacteria and fungi.

ORGANO-SULFUR BIOCIDES

They are very effective against aerobic bacteria, fungi and algae. They are less effective against sulfate-reducing bacteria (due to reaction with sulfides). It has been found that the organo-sulfur biocides are much more effective in cooling systems when used in conjunction with chlorine.

One of the organo-sulfur type biocides is effective against aerobic bacteria and fungi at pH levels below 7.5. It is much less effective against algae and sulfate reducing bacteria.

Other types such as Bistrichlorosulfones, are not very effective biocides in cooling water treatments. They have some effect against aerobic bacteria, but are less effective against S.R.B., fungi and algae.

Carbamates are very effective fungicides, but less effective against aerobic bacteria, S.R.B. and algae. Carbamates become much more effective against aerobic bacteria when used in water containing high levels of iron and zinc and heavy metals such as chromium. This is due to hydrolysis of biocidal products, which are catalyzed by metal ions. These products are more effective at high pH levels and are slow-acting.

ORGANO-NITROGEN BIOCIDES

This is a large group of biocides. Some of them are effective bactericides, but less effective against other organisms. Their main disadvantage is their high toxicity (creating toxic fumes and handling problems) and low water solubility.

Some other biocides belonging to this family, include such products as dodecylguanidine salts, are effective bactericides and algaecides but are less effective fungicides. Many of these products are cationic (positively charged) molecules that may cause severe foaming problems. They become adsorbed to many surfaces and may be lost to the system. They are good surfactants and have many properties in common with quats and amines.

AMINE SALTS

The amine salts are cationic biocides and are good surfactants. The quats are effective against aerobic bacteria, S.R.B. and algae, but less effective against fungi. Polyamine salts are effective against aerobic bacteria and S.R.B., but less effective against algae and fungi. Both quats and amines are fast-acting biocides: they are generally more effective in combination with chlorine.

HEAVY METALS

Heavy metals include copper salts and tin salts. Copper salts are good algaecides but very poor fungicides and bactericides. They cause corrosion if used in cooling systems. They are generally added to ponds and lakes to control algae.

Tin salts are good general-purpose biocides. Formulated with quats to increase their dispersability, they have been found effective against S.R.B., fungi and algae. They are less effective against aerobic bacteria. These biocides have proven useful for the control of fungal wood rot.

WHAT IS SULPHATE REDUCING BACTERIA ?

During recent years, there has been a significant increase in the incidence of corrosion caused by Sulphate Reducing Bacteria (SRB). This type of corrosion has caused major damage to cooling water systems. The effects of this type of corrosion can be found in cooling tower sumps, recirculating lines and condenser water boxes.

Reasons for this increase include the change from chromate-based programs to modern corrosion inhibitors along with the change to more alkaline-based programs. Chromates were known to have a bacteriostat effect, which helped prevent growth of SRB.

Indications of SRB include reddish or yellowish nodule on metal surfaces that when broken exhibits black corrosion by-products. When the complete nodule is removed, a bright silver pit is found. Corrosion by-products are non-magnetic. Severe localized pitting is evident. If hydrochloric acid is added to the black deposit, hydrogen sulphide will be released giving off a "rotten" egg odor.

The two most common species of these bacteria are *Desulfovibrio desulfuricans* and *Desulfotomaculum nigrificans*. These organisms favor an anaerobic (oxygen free) environment. This does not mean that sulphate reducers will not grow in oxygen rich cooling waters. SRB can thrive under deposits where no oxygen is present even though aerobic conditions exist in the main body of water. Problems with SRB will occur more readily in systems with concurrent fouling problems. Excessive amounts of dirt, algae, oils and other bacteria will provide ideal conditions for growth. SRB will co-exit with IRB (Iron Reducing Bacteria) creating massive problems. Even small amounts of oil and grease will provide nutrients for growth. Stagnant water and low flow conditions will increase the chances of SRB growth.

SRB obtain their energy from the anaerobic reduction of sulphates. Sulphates are available in most waters due to outside contamination. This bacteria contains an enzyme (hydrogenase) which enables it to use elemental hydrogen generated at the cathodic site to reduce sulphate to hydrogen sulphide. It therefore acts as a cathodic depolarizing agent. The corrosion of iron by this process is very rapid and unlike ordinary rusting, is not self-limiting.

Once SRB begins to grow in a system, it becomes very difficult to eliminate. A prevention program is much more effective than trying to clean a fouled system. Keep excessive dirt from settling in basins with the use of dispersants and side stream filtration. Prevent cooling water contamination by oils and grease. Even the smallest amount may cause problems. Make sure contamination is not coming from the surrounding area. Check for bathroom and kitchen exhaust vents. Make sure incinerator stacks and diesel exhaust are not entering the tower. Keep the system flowing. Prevent stagnant water.

Control of this type of bacteria can be accomplished with good housekeeping and proper biocide treatment. These biocides will all control SRB in bulk water. When the bacteria become encapsulated, control then becomes a problem. Many biocides will not penetrate the protective capsules. Some are even deactivated by the sulphide released by the bacteria.

The addition of a bio-dispersant and penetrate will help the biocides enter the bacteria cells, providing a much better chance of kill. Research and field experience has shown that an aldehyde-based biocide has been very effective in eradicating these bacteria.

If contamination does occur, a special clean out program should be designed for each system. All aspects of the water treatment program need to be examined. Complete control of these bacteria is necessary to prevent recontamination.

WHAT IS IRON REDUCING BACTERIA ?

Iron bacteria are a group of microorganisms found in industrial waters, streams, lakes, wells and potable water supplies. Recently, these organisms have gained recognition in the industry due to their effect on process equipment and finished products.

Iron bacteria are considered capable of withdrawing iron present in waters and depositing it, in the form of hydrated ferric hydroxide on or in their mucilaginous secretions. These large secretions, commonly referred to as slime, will impart an unpleasant odor to drinking water. As these microorganisms increase in number, the water may become more turbid, and the color of the water will turn "brick-red". Hence, the common reference of "red water."

In addition to discoloring the water, this group of microorganisms produces undesirable accumulations in pipes, nozzles, ponds etc. These deposits will in time slough off and plug lines, foul pumps, valves and/or affect the quality of finished products. These bacteria oxidize ferrous ions to ferric, which is precipitated as ferric hydrate. Iron may be obtained from the pipe itself or from the water being carried. These bacteria may initiate pitting and tuberculation in iron pipes. They are partial to wells, or outfalls where enters a stream. While these microorganisms are considered as aerobic, requiring oxygen to survive, they have been found to grow in waters with very low oxygen content.

The principal distinguishing characteristic between iron bacteria and other types of microorganisms is their ability to absorb and accumulate iron and /or manganese, when grown in environments, which contain these elements. These organisms deposit iron and manganese salts around their cells which result in the characteristic reddish brown – black color. Iron bacteria are considered autotrophic (self-sufficient) organisms, oxidizing iron compounds as a source of energy. In general, the bacteria prefer lower temperatures but are known to grow at temperatures, which range from 5.5 to 8.2 with an optimum pH around 6.5. These organisms are not affected by light and have been found to grow in exposed areas, in shade as well as complete darkness.

Identification of iron bacteria is extremely difficult. While these organisms grow extremely well in recirculating water, laboratory attempts using usual cultural media methods have not been successful in the past. Therefore, it is not possible to evaluate the number of these organisms in water supplies with the usual bacteriological procedures. The satisfactory procedure for examining the population index of these organisms is direct microscopic analysis of the water after staining. This method also proves difficult due to difficulties in culturing large quantities for analysis.

Usually surrounded by a tubular "mucilaginous" sheath that hardness and becomes impregnated with ferric hydroxide, iron bacteria can be difficult to control. Chlorination has been used for control in bulk waters for many years; however, there are inherent drawbacks in the use of these products. High chlorine demand due to organic matter and iron levels has shifted the emphasis for control to the use of non-oxidizing biocides, such as quats, as well as organo-sulphur compounds.

LEGIONNAIRES DISEASE: A SYNOPSIS

In 1976, there was an outbreak of 221 pneumonia cases associated with an American Legion Convention in Philadelphia, Pennsylvania. It was determined that the *bacterium legionella* was the causative agent of the

There are currently 23 recognized species of legionella. Of these, only 11 have been isolated from infected humans. One of these species, *Legionella pneumophila* has been implicated as the causative agent for approximately 85% of all known cases of legionellosis. The same species of the bacterium can cause either the pneumonia or Pontiac Fever. Still, it is not known what factors influence the bacterium to cause one form of the disease instead of the other.

Using a technique called isoenzyme typing, each serogroup can be further subdivided. The use of this technique has resulted in the discovery of 62 genetic variations of L. pneumophila serogroup.

The identification of a legionella species in a given water source does not prove any association with disease. This is due to the genetic diversity of the organism.

Close surveillance of outbreaks is the primary indirect control measure for legionellosis at this time.

So how are responsible water treatment professional supposed to handle questions regarding Legionnaires Disease? The following common sense recommendations are not designed to eliminate legionella, but rather to minimize the potential of the bacteria to get out of control and cause on outbreak of disease.

Keep the system operating within the established parameters. The accumulation of suspended matter and organic matter can contribute to the proliferation of legionella.

Undertake an effective biocide program that includes two, alternating biocides that function in differing manners. (**i.e. alternate a quaternary ammonium based biocide with a carbamate biocide.**) The control of other microflora within a system can and does have a direct impact upon the growth of legionella.
Monitor levels of other bacteria within the system. Since legionella grows at a rate slower than most other bacteria, it is probable that the system would experience other problems prior to legionella becoming a problem.

Inspect the site for air intake sites in the vicinity of the cooling tower. By minimizing the exposure of persons to water vapors from the cooling system, you can minimize the potential for an outbreak of disease.

By following the above recommendations, best possible protection against Legionnaires Disease can be achieved. The information contained in this article represents a summary of the information currently available. It is designed to be used in an informative manner only.

WHAT ARE THE METHODS FOR THE DETECTION AND ENUMERATION OF MICROORGANISMS ?

The most common field methods for the detection and enumeration of microorganisms are as follows:

1. *Plate Counts,* using a solid agar nutrient medium as the growth substrate in Petri dishes, have been used for many years for identifying and enumerating bacteria and fungi. More recently the introduction of Petrifilm Plates has made on-site plate counts much easier.

2. *Dipslides.* These use an agar nutrient medium placed on a plastic tab or slide. Counts are obtained by dipping the slide in the water sample and then incubating the slide for 24 or 48 hours. Numbers of microorganisms are estimated by comparing the slide to a standard chart. This method is only semi-quantitative.

3. *Adenosine Triphosphate (ATP) Analysis.* A measurement of A.T.P. levels provides some indication of the total biomass contained within a water mass. Measurement of A.T.P. will not distinguish between the types of cells contributing to the biomass, e.g., bacteria, fungi or algae.

BIOCIDE KILL TEST PROCEDURE

The aim of a kill test procedure is to select a biocide that will produce good microbial control within an industrial water system at levels that are cost-effective.

The residence time or Holding Time Index (HTI.) within the cooling system should be determined beforehand. Various biocides should be tested within the system at various concentrations, using an exposure time equivalent to the residence time of the system. Thereafter, the number of surviving microorganisms can be determined using plate counts, dipslides or A.T.P. analysis.

The selected biocide should also be compatible with other chemical treatments such as scale inhibitors, corrosion inhibitors and dispersants.

APPLICATION TECHNIQUES

The variations in physical characteristics of cooling water systems are vary large. While a single slug addition of biocide may be best for one system, continuous addition may be the right answer for another. For example, chlorine is normally fed for a total period of one hour in 24, i.e. a 20 minute application each eight hour shift.

Addition of a specific biocide at the tower sump may be recommended for one system, while addition of the biocide to certain sections of the plant (where the problem is severe) might be advisable in other cases.

Other important factors that must be considered are effluent requirements, toxicity, and the effect on the corrosion and scale inhibiting program.

The acceptable level of organisms present in the system can vary from plant to plant.

The performance of regular microbiological analysis will provide information on :

(a) The total bacterial count in the system.

(b) The concentrations of organisms of different types in the system.

(c) The effect of the addition of biocides on the organisms.

(d) Whether the frequency and rate of treatment has to be changed to maintain control.

(e) The influence of the presence of nutrients on the system.

VALUE OF THE TOTAL BACTERIAL COUNT

This refers to the total aerobic bacteria found in the bulk water. Historical counts on a particular system are needed to gain insight into the total count data. Nutrient level, temperature and experience gained in other systems should be considered to assess the degree of control required and the type of biocide and programme best suited to a particular system.

A single microbiological analysis only represents conditions at the time of sampling. Probably of more importance is the trend in microbiological activity. Results ideally should be plotted graphically to determine the minimum effective dosage of the biocide in the system, and to establish the minimum frequency of addition needed to maintain control.

Continual dosage of the same type of non-oxidising biocide to a population of micro-organisms will consistently kill a very high percentage, but it is possible that some organisms will be resistant to a specific biocide and others may develop a resistance. The resistant organisms or strains will than multiply rapidly in the absence of competition and a different biocide will then be required. Therefore, it is good practice to institute a programme of alternating different biocides.

All microbiological problems associated with cooling systems should be investigated by specialists, so that the benefit of their experience may be applied in establishing the needs of individual plants.

SIGNIFICANCE AND INTERPRETATION OF MICROBIOLOGICAL ANALYSIS

1.2. CORROSION ATTRIBUTABLE TO SULPHATE-REDUCING BACTERIA HAS THREE MAIN CHARACTERISTICS

(a) It occurs in anaerobic environments in the presence of water. Encrustations or 'tubercles' on the metal harbour sulphate-reducing bacteria and provide suitable anaerobic conditions for corrosion. When subjected to intermittent aerobic/ anaerobic conditions, iron objects often corrode faster than

under constant anaerobic conditions. This is probably due to secondary corrosive reactions resulting from the activities of these bacteria.

(b) The corroded metal is pitted rather than evenly corroded. The rate of pitting increases with time, indicating that the process is of an autocatalytic character. Corroded pipes tend, therefore, to perforate rather than desintegrate.

(c) Cast-iron leaves a carbon residue at the site of corrosion, and the metal becomes 'graphitised'. Both iron and steel form a corrosion product containing much iron sulphide.

While these limits may be acceptable in certain plants, different limits (higher or lower values for slime forming and total bacterial count) may be needed on other plants. In all cases, however, there should be an absence of sulphate reducing bacteria.

1.3. MICROBIOLOGICAL MONITORING – Use of Dip Slides.

Dip slides are used as a guide to on-site testing for the level of activity of micro-organisms within cooling systems. Specific record sheets for dip slide results can be laid out in graphical form. Such progressive graphical records will indicate clearly trends within a given system that will be apparent at a glance.

It cannot be emphasised too strongly that dip slides will only show trends in micro-organisms activity. The results cannot be taken as specific scientific quantitative findings such as would be obtained by TVC results obtained in a microbiological laboratory.

There is a unfortunate tendency to over-react to high counts obtained from dip slide results.

The following procedures should be observed.

1. The sampling procedure must be carried out in such a way that no external contamination can occur and the sample obtained is representative of the system water.

2. To ensure reproducible results an incubator set between 30-35^{0}C must be used. Always allow the same time period for incubation, eg. note a reading after 24 hours, then again after 48 hours if there is a significant change.

3. Log the results on the weekly graph sheet, note any trends, and take another dip slide to check the results if a high reading has been obtained. Further high readings will require checking by submitting a TVC sample to a microbiological laboratory. Remedial action, as dictated by site protocol may be required.

4. Boxes of dip slides are date stamped and only those within a given date should be used. Results may be unreliable if old or out of date slides are used.

The limitations of dip slides can be summarised :

a) Providing the time / temperature relationship is constant, the slide results are mainly reproduce but the method does have inherent difficulties.

b) The small area of agar on the slide causes crowding of the colonies. Some may develop with no colour and thus be overlooked.

c) Surface active agents may be absorbed which may prevent the development of many colonies, leading to inaccurate results.

d) Only the organisms capable of growing on the medium used and at the temperature of incubation chosen will develop and a number of dead organisms will go unrecognised.

e) Dip slides can not give any indication of the presence of Legionella, so if dip slides results show NIL or very low counts, the absence of Legionella cannot be assumed.

f) Dip slides will not give any indication of specific micro-organism activity.

COOLING SYSTEM - MAINTENANCE CONTROL

Wood in cooling tower is subject to three main types of deterioration: -

1. **PHYSICAL**
2. **CHEMICAL**
3. **BIOLOGICAL**

THE THREE TYPES OCCUR SIMULTANEOUSLY :-

1. **PHYSICAL** : Wood is composed of cellulose, lignins and natural extractives. The cellulose is similar to cotton fibers and gives wood its strength. The lignins provide the cementing agent, which holds the fibers together. The extractives create wood resistance to decay. It is these substances, which make redwood so durable. However, the extractives are soluble and are leached from the

wood by water. Although this action does not seem to affect the strength of wood, decay may take place more rapidly.

2. **CHEMICAL** : Chemical deterioration usually causes delignification, indicated by the bleached appearance of the wood. The chemicals commonly responsible for this attack are oxidizing agents such as chlorine and alkalis such as calcium bicarbonate, calcium carbonate chemical attack most frequently take place in the fill and in the flooded portions of the tower. It can be controlled by maintaining pH around 8.0 - 8.5. The free chlorine residual should be maintained at less than 1.00 ppm when using intermittent chlorination.

3. **BIOLOGICAL** : Attach occurs as surface rot and as internal decay. The organisms feed on cellulose, leaving the lignins; consequently, the wood loses much of its strength. Internal decay in cooling towers occurs in the plenum areas, cell partitions, doors and fan housing and supports; surface rot occurs in the flooded area.

The agent, which prevents chemical deterioration of wood, also minimizes biological deterioration of the surface type periodic addition of non-oxidizing biocide to the water minimizes the attacks. In the areas subject to internal decay, lumber is sprayed with preservatives that are toxic to the organisms. This protective measure must be taken before serious in factions starts. A regular spray procedure should be considered for preventive maintenance. A periodic examination of the tower should be made by sending the samples of wood to qualified biological laboratory. These studies serve as basis to determine the beginning of a preventive spraying programme. Fungi display considerable tolerance to wood preservatives. The normal lifetime of a cooling tower wood is perhaps 12-16 years but in a place with humid climate, a tower may last only 6 or 7 years.

Note: - Viable plant counts of 100,000 - 500,000/ml indicate a biologically clean system.

What is the SOLUTION TO COOLING WATER PROBLEMS ?

Chemical treatment is the only cost effective and reliable solution to the water problems. The chemicals, which are used in treatment of water, are: -

1. Antiscalants 2. Corrosion Inhibitors 3. Biocides 4. Antifoulants

ANTISCALANTS: They increase the solubility of Ca (calcium) and Mg (Magnesium) salts in the water and thus scaling potential is reduced or antiscalants also interfere in the process of formation of crystals of salts. Crystals have a definite structure unless the structure is formed, as its natural shape the crystal cannot be very hard. The antiscalants present in the cooling water are attached in to the crystal growth sites and thus crystal growth is stopped. Even if the crystal grows from a different site, it is irregular and structurally weak. The scales formed by such a crystal are very weak and fluffy and normally washed off by water velocities.

The best-known antiscalants world over are called "**ORGANO PHOSPHONATES"** which are being used in modern treatment approach for cooling water system.

CORROSION INHIBITORS: These are class of compounds, which form a monomolecular layer on corrosion sites. As you are aware that any type of corrosion is an electrochemical reaction. So, a cathode and an anode must be involved for corrosion reaction to complete. Based on these corrosion inhibitors are also divided in to general-purpose cathodic and anodic inhibitors.

All these will block corrosion site and restrict corrosion to take place. Ortho-phosphate, poly- phosphate, azoles, molybdates and zinc are few of the most widely used corrosion inhibitors in cooling water.

BIOCIDES: - As the name suggests this is the class of compounds which "Kill Life". All biocides will react in some way or other with the life process of the cell. Some biocides just burn the cells. Some of the biocides will get into the cell and will act as poison. Some other will rupture the cell walls and some will kill the spores which will not allow further growth of any life forms in water. Most widely used biocides are quaternary ammonium compounds (quats), dodecy / guanidine salts and various other proprietary chemicals.

Development of effective antimicrobial program is aided by an understanding of the mode of action of the products, the system to be treated and environmental effects. All these factors play a role in the selection of an effective and economical microbiological control program.

ANTI-FOULANTS: - Anti foulants are also called dispersants. They are class of compounds polymeric in nature. These compounds can be developed for an individual known foulant or can be general dispersant as well. As the name suggests, they are polymers, which disperse the suspended particles.

All the suspended particles have a small electrical charge on them. Dispersants are short chain molecular compounds, which will attach themselves to suspended particles and increase the charge on the particles. Once the charge is high, like particles can not come together. Thus, the dispersants are kept suspended in water for a long period.

HOW TO EVALUATE A NEW PROPOSAL OF WATER TREATMENT CHEMICALS FOR YOUR BOILER / COOLING SYSTEM ?

When contemplating a change in water treatment programme because of unsatisfactory results or when putting a new system in operation, it is better to discuss the matter with representative of a reliable, experienced and good company.

Usually only one programme is offered for controlling scaling, corrosion etc. This helps to sustain the myth that any water supply can be treated effectively by single chemical. When considering such proposals you should always insist on professional approach. After all, you are legally responsible for the safety of your employees and the harmful materials discharged to public water. The days are gone when a chemical identified only by number or meaningless name was saleable.

YOU MUST KNOW WHAT YOU ARE BUYING.

Every cooling/heating system presents a unique combination of equipment, water parameters, blow down and control consideration. Proper selection of a sound water treatment programme requires collection of considerable amount of information.

After making a detailed survey of the system including its design, material of construction, current treatment a recommendation in the form of proposal is made. Since monitoring a water treatment programme is the key to success, the proposal must include method of control monitoring and follow-up. Corrective actions are required for an effective cooling / heating water treatment programme. The goal of monitoring is to identify potential problem before they occur.

WRONG SELECTION OF WATER TREATMENT CHEMICALS IS HARMFUL

Wrong selection of water treatment chemicals can be harmful for the system (Boiler / Cooling) and can cause following direct / indirect losses to your Boiler / Cooling System.

- Loss of efficiency (due to scaling).
- Unnecessary shut downs.
- Accidents.
- Loss of metals and alloys in your costly equipment (due to corrosion).
- Algae growth in cooling tower (over feeding of phosphates).
- Loss of production.
- Loss of money (cost of chemicals).

Numerous combinations of chemicals have been recommended for treating cooling / boiler water by various water treatment chemicals manufacturing companies. Some perform well; others are virtually useless while a few are harmful.

When you buy "Water Treatment Programme" you actually buy :

1. Chemicals

2. Service

Scope of job of water treatment company is : -

1. To do initial survey i.e. check out the various properties of water and survey the plant details.

2. Design the programme as per your requirements.

3. Monitor the programme regularly.

Here it is important to note down only by doing above three things properly, water treatment company can produce the desired result. Which means, your system must run...

(1) Scale free

(2) Corrosion free

(3) Free from any other water related problem

Every cooling/heating (boiler) water system presents a unique combination of equipment, water chemistry, contamination, blow down and control consideration. A chemicals supplying company must take following details into consideration before supplying chemicals

--- THE SYSTEM DESIGN AND DATA

--- RAW WATER CHEMISTRY

--- EXTERNAL TREATMENT / MAKEUP WATER CHEMISTRY

--- EFFLUENT CONSIDERATION

--- MATERIAL OF CONSTRUCTION

--- OPERATING TEMPERATURE
--- PRESENT TREATMENT

--- GEOGRAPHICAL LOCATION OF PLANT

PRODUCT	RECIRCULATING LINE AFTER BLOWDOWN	TOWER BASIN
Corrosion Inhibitor	Primary	Secondary
Deposit Control Agents	Primary	Secondary
Biocides	Primary	Secondary
pH Adjustment Chemicals Acids	Primary (use acid resistant injection/corporation stop)	Secondary

Standard methods for feeding cooling water products include:

CYCLE CONTROL	Bleed-off Controller Chemical Pump Bleed Solenoid

Chemical feed and system bleed-off occur simultaneously. Special attention must be made to ensure chemicals are not lost during blowdown.

METER TIMER CONTROL	Water Meter / Timer Bleed-off Controller Chemical Pumps Bleed Solenoid

Chemical feed is initiated independent of bleed-off by a command from a make-up water meter with a contacting head.

pH CONTROL	On Line pH Monitor with Lockout Timer

This system must be coupled with a limit switch or lockout switch to ensure safety. Acid feed should never be controlled with a cycle control system.

MATERIALS OF CONSTRUCTION

Since most cooling water chemicals are usually acidic in nature (unless neutralized), polyethylene tanks are

used for mixing. We recommend glass filled polypropylene for all wet ends on pumps. Ceramic ball valves and Teflon seats are impervious to most kinds of chemicals used in cooling systems. Feed lines are most commonly polyethylene or schedule 80 rigid PVC. Care should be taken to protect these lines especially if they carry 66 deg Baumé sulfuric acid. Stainless steel tubing can be used for acid feed lines. It is recommended that either 304 or 316 be used and that it be no larger than ½ inch diameter. Do not use copper for chemical feed lines.

COOLING SYSTEM START-UP AND SHUT-DOWN

Even if a cooling system is well taken care of during the operating season, damage can occur if proper season start-up or end of the season shutdown procedures are not followed.

At the start of the season when cooling systems are first filled with water, the corrosion mechanism will also begin in these unprotected systems. Many systems are filled with fresh water and are then run intermittently. Chemical treatment levels remain low because the system has not cycled up to normal levels. Due to interruptions in operations, biocides may not be added on a regular basis. Oils and greases used in preparing the systems for operation may initially contaminate waterside surfaces. Lack of biocide addition along with organic contaminants provides a perfect atmosphere for bacterial growth that may cause severe corrosion. Stagnant water allows for increased microbiological activity along with dropout of suspended impurities.

Without proper start-up, conditions occur that will result in problems that may damage the system and take most of the cooling season to correct, if, even possible. The following steps will help prevent initial problems:

1. If the cooling tower basin is dirty from sitting idle, flush with fresh water to drain.
2. Upon filling with fresh water, add twice the normal level of corrosion inhibitor and circulate for 48 hours. If possible, use a special product designed specifically for pre-filming a system such as ARC-1029 (11).

3. If a system is running intermittently, make sure biocides are added and circulated for at least two hours on a weekly basis.

4. Initially run the system at lower cycles of concentration to prevent dropout of foulants during off-line times. It may also be desirable to add a special dispersant to help keep impurities in suspension.

5. Use common sense. Try not to drain the system piping once filled. If the system pipe is drained, rust will begin to form. Flushing and pre-filming will need to be done again.

Proper start-up will extend the life of the cooling system piping and equipment. Fewer problems will be encountered during the regular cooling season.

6. If the condenser is to be laid up wet, the unit should first be drained of all tower water. Add fresh make-up water along with a non-oxidizing biocide and a high level of corrosion inhibitor for corrosion protection.

7. Chemical feed and control systems should be taken off-line and cleaned. Conductivity and pH probes should be removed, cleaned and properly stored. Chemical feed pumps should be flushed with fresh water.

By following these suggested steps for cooling system start-up and shutdown, severe problems can be averted. These preventive steps will extend the life of cooling systems, provide more efficient chemical use and possibly save a tremendous amount of energy

HOW TO MAKE A COOLING TOWER COMPLETELY DISAPPEAR ?

1. When installing a new cooling tower, only purchase the least expensive unit you can find. Do not consider costly options such as hot-dip galvanizing, coal-tar epoxy, or other coatings, which would segregate, tower internals from cooling water.

2. Do not perform pre-operational cleaning on a new tower or pre-seasonal cleaning on an idle tower. After all, what benefit can possibly be realized from using a little bit of detergent?

3. Do not perform regular preventive maintenance on cooling tower components. Don't be concerned with the fan motor or blades, silt in the basin, algae in the distribution pans, condition of the fill, etc. Problems can never develop in these areas. Well, hardly ever.

4. Do not become directly involved with you water treatment program. Leave everything to your water treatment representative.

5. Do not assign anyone to conduct daily testing, monitor chemical inventories, or work closely with your water treatment representative. Surprises can be quite exciting, don't you think?

6. Do not periodically test for bacterial activity in cooling water, silt, etc. Whoever heard of certain strains of bacteria completely penetrating a cooling tower basin?

7. Do not install top-quality, reliable chemical feed and monitoring equipment. The money you save in this area can best be used in another area, such as routine acid cleaning. (See next item.)

8. Do not hesitate to flush your cooling system with acid cleaners on a regular basis. A quick fix is preferred to the more difficult Controlled Treatment Method.

Chemical treatment alone cannot solve the problems associated with suspended particulates in the cooling system. Relying on blowdown alone is a hit and miss proposition at best. The best approach is a combination of methods, including the use of automatic self-cleaning filters.

HOW WE CAN MAINTAIN COOLING TOWER SYSTEM ?

Proper maintenance is essential for prevention of illness, as cooling towers that are not maintained properly can be a source of Legionnaires disease.

Cooling Towers can be maintained by:

- At least one monthly inspection of cooling towers .
- Regular water treatment.
- At least one monthly microbial testing of the tower for total bacteria .
- Complete cleaning and disinfection of the tower every three to six months in accordance with the guidelines.
- All internal wetted surfaces of the tower, particularly the sumps and fill, shall be cleaned by high-pressure water, steam or other effective method.
- Biocides should provide a broad-spectrum control of microorganisms.
- Cleaning of the tower prior to start up, following seasonal shut down.

Premises owners should record information regarding (keep a log book):

- Layout of the cooling tower system, operating procedures.

*Procedures and frequency of maintaining, cleaning and disinfecting the **cooling tower.***

- Name and contact number of the company responsible for servicing the tower

WHAT IS LEGIONELLA ?

Legionella is a bacterium associated with water and is widespread in the environment. It can be found in lakes, rivers and creeks and also in artificial environments including Cooling Towers associated with air conditioning, industrial processes and in reticulated water systems. These artificial systems can provide conditions that allow for microbial growth in large numbers. The Legionella bacteria cause legionnaires' disease.

Even if a cooling system is well taken care of during the operating season, damage can occur if proper season start-up or end of the season shutdown procedures are not followed.

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Without proper start-up, conditions occur that will result in problems that may damage the system and take most of the cooling season to correct, if, even possible. The following steps will help prevent initial problems:

1. If the cooling tower basin is dirty from sitting idle, flush with fresh water to drain.

2. Upon filling with fresh water, add twice the normal level of corrosion inhibitor and circulate for 48 hours. If possible, use a special product designed specifically for pre-filming a system such as ARC-1029 (111).

3. If a system is running intermittently, make sure biocides are added and circulated for at least two hours on a weekly basis.

4. Initially run the system at lower cycles of concentration to prevent dropout of foulants during off-line times. It may also be desirable to add a special dispersant to help keep impurities in suspension.

5. Use common sense. Try not to drain the system piping once filled. If the system pipe is drained, rust will begin to form. Flushing and pre-filming will need to be done again.

Proper start-up will extend the life of the cooling system piping and equipment. Fewer problems will be encountered during the regular cooling season.

Just as proper start-up is important to the integrity of the cooling system, proper shutdown and lay-up are also extremely important. Corrosion, fouling and scale may form in a cooling system that is improperly taken off-line at the end of the cooling season. Many cooling systems are again operated on an intermittent basis. Poor or no chemical treatment normally occurs during this time. Suspended solids will begin to dropout during periods of off operation. High levels of scaling impurities may also result in precipitation. Lack of biocide addition will allow microbiological growth. When pipes are drained and then refilled, the corrosion

process will begin resulting in system metal loss. If piping is not properly taken care of after shutdown, out-of-service corrosion can cause a severe problem.

Out-of-service corrosion normally shows up during the following cooling season when iron scale or so called pipe slag breaks loose and begins to plug distribution nozzles, pump strainers and even tube bundles. Pipe slag forms when non-continuous wetted pipe begins to rust and water impurities are left behind after evaporation. Pipe slag can be as thin as a piece of paper or as thick as a silver dollar. Pipe slag that is wedged in condenser tubes will result in lost flow and loss of cooling efficiency. This type of problem can be solved by taking proper steps when taking a system off-line for the season.

The following procedures will help maintain the integrity of the cooling system during annual shutdown.

1. As the season winds down, decrease cycles of concentration. This will prevent high levels of dissolved and suspended solids from dropping out when the system is off-line.

2. Before shutdown, add a non-oxidizing biocide at maximum level to kill any biological growth that may be in the system. Remember stagnant water provides conditions that maximize biological growth.

3. A separate dispersant and/or bio-dispersant may be added to loosen and penetrate existing foulants.

4. To control out-of-service corrosion, a special post-film chemical should be added to the system and circulated. The use of corrosion inhibitor will provide superior corrosion protection for the system metals. Use of this type of product will inhibit the formulation of pipe slag. This product should be added approximately three days before system shutdown.

5. Once the system is brought off-line, drain all pipes and tower sump to prevent freezing. If possible, power wash or flush all mud and debris from the tower sump.

6. If the condenser is to be laid up wet, the unit should first be drained of all tower water. Add fresh make-up water along with a non-oxidizing biocide and a high level of corrosion inhibitor for corrosion protection.

7. Chemical feed and control systems should be taken off-line and cleaned. Conductivity and pH probes should be removed, cleaned and properly stored. Chemical feed pumps should be flushed with fresh water.

By following these suggested steps for cooling system start-up and shutdown, severe problems can be averted. These preventive steps will extend the life of cooling systems, provide more efficient chemical use and possibly save a tremendous amount of energy

WHAT IS LANGELIER INDEX ?

The solubility of calcium carbonate and calcium bicarbonate in water is of particular importance because calcium carbonate is the most significant scale-forming compound. The solubility of calcium carbonate is affected by temperature and by other salts present but the factor of greatest significance in evaporative cooling systems is the aeration which takes place in the cooling tower, thus removing carbon dioxide. The point at which scaling occurs if often determined by temperature, but it can also occur occasionally at or near the aeration zone.

Many standard text books deal with this in detail, but the following is a very simplified interpretation (see Appendix 11). Calcium carbonate is held in solution in water (at pH 5.5.- 8.5 by carbon dioxide). Part of the CO_2 helps to form the bicarbonate ion but excess carbon dioxide over that needed to produce the bicarbonate ion is needed to keep it in solution. If insufficient carbon dioxide is present, the bicarbonate will be unstable and some of it will decompose to precipitate carbonate and release carbon dioxide until equilibrium is reached. If excess carbon dioxide is present, it will be available for dissolving more calcium carbonate.

$Ca(HCO_3)_2\ CaCO_3 + CO_2 + H_2O$

Professor Langelier introduced the concept of "saturation pH value" or "pH"s, at which a water of any given composition (alkalinity, calcium content, dissolved solids) is in equilibrium at any given temperature. PHs can be calculated from physico-chemical data or an approximate value can be obtained by measuring Ph value after bringing the solution into contact with calcite ($CaCO_3$) crystals and allowing time for equilibrium to be established.

The difference between the actual pH value and saturation pH is known as the "Saturation Index" or "Langelier Index".

Langelier (Saturation) Index = pH - pHs

If the Index is positive, the water is supersaturated and will tend to precipitate calcium carbonate. If negative, the water is capable of dissolving more calcium carbonate. If zero, the water is just saturated.

The Index affects corrosion only in so far as it affects calcium carbonate. If positive, corrosion will often be controlled but only if the calcium carbonate is precipitated in certain forms. In practice, many waters with a positive index are not corrosive but they may throw down a significant quantity of scale. In a system with a range of temperature, scaling at one point may indirectly bring about corrosion at other parts. Under some

below the lower limit of pump output. Continuous dosing can be applied to all sizes of cooling systems at all concentration factors but is only fully effective in systems which operate under constant conditions.

2.1.3 INTERMITTENT DOSING LINKED TO SYSTEM OPERATION

A simple pump or pump timer can be powered from the cooling system controls in such a way that chemical dosage only takes place when the system is in operation. This offers some improvement over continuously running pumps but is still incapable of compensating for changes in system water quality.

2.1.4 PROPORTIONAL DOSING RELATED TO BLEED

System bleed may be controlled by one of three methods; simple timer, conductivity or make-up water flow. The signal from any one of these can be used to initiate chemical dosing. The electrical conductivity of the system water is analogous to the degree of concentration which has taken place in the system and hence the amount of make-up water which has been introduced.

Every time the conductivity of the system water reaches a pre-determined value, a timer can be actuated which allows a dosage pump to run for a period which will add the requisite amount of inhibitor, in relation to the make-up that has entered the system. The ability of this control method to respond to system variations depends on the level sophistication used to control the bleed.

2.1.5 PROPOTIONAL DOSING RELATED TO MAKE-UP WATER VOLUME

Proportional dosing maintains a near constant chemical level by dosing in proportion to a varying make-up water rate. In other words, the treatment requirement is based on the make-up water quantity and the injection rate varies as the water make-up changes.

Mechanically this method of dosing is achieved by the use of an impulse water meter in the make-up line which activates a chemical dosing pump.

Proportional continuous dosing can be applied to all cooling systems and is of particular benefit to systems which operate under widely varying conditions. The labour requirement is merely to replenish the solution tank and to check occasionally on the dosing pump.

2.1.6. DOSING CONTROLLED BY A SENSOR

The ideal way of controlling a chemical in a system is to measure its concentration (or a variable directly related to it) and using the result of that measurement to control the dosing. Specific sensors such as pH or redox probes are used to control the dosing of acids and oxidization biocides respectively.

The incorporation of specific tracers into treatment chemicals can be used to extend the applicability of this technique.

2.1.7. DOSING PRECAUTIONS

The treatment method used for any cooling system is a balance between several factors, but for all systems and all the methods available, the following basic points apply:

(a) It is essential that frequent checks are made on all equipment.

(b) It is essential to instigate a system that will ensure that chemical solution tanks are never allowed to run dry.

(c) It is important to give some consideration to the actual point of injection of any treatment chemicals. The main criterion is that the injection point must allow full and rapid mixing of the chemical solution into the bulk water.

(d) Many of the chemicals used in water treatment are corrosive in concentrated form, being acidic or alkaline. Selection of materials for injection pipework and pumps must take this into consideration. Specialised injection fitting may be required to prevent strong chemicals being in direct contact with pipe walls, cooling tower panels etc.

(e) Dosing systems should be designed to minimize the handling of all chemicals, pumps and equipment are readily available to draw chemicals direct from the supplier's container. Where chemicals are to be handled there are COSHH risk assessment implications in both the need to lift drums and the risk of splashing.

This section is not intended to be an exhaustive discussion on dosing methods and equipment and therefore there are many slight variations which have of necessity been omitted.

2.1.8. BIOCIDE DOSING

A single oxidising biocide may be successfully dosed on a continuous basis, whereas non-oxidising biocides are normally dosed on an intermittent shot basis. Shot dosing is the preferred technique because intermittent application prevents microbiological acclimatisation and is a more economic treatment method. Biocides are different from other chemicals in that bacterial/algal population is used as a yardstick for determining the frequency and concentration of biocide doses rather than the maintenance of a certain biocide level in the recirculating water.

Continued dosing of the same non-oxidizing biocide to a cooling system can cause the bacterial/ algal population to develop an immunity to an individual biocide and it is normal practice to use two biocides and alternate them at suitable intervals. Whilst manual dosing is possible, the necessity of ensuring regular dosing at intervals with two biocides may be rather difficult in practice. Automatic control systems are available which ensure that this system can be operated without human error. Biocide dosing must comply with current guidelines.

DISINFECTION OF EVAPORATIVE COOLING SYSTEMS

1.1 ON-LINE CHLORINATION

Successful chlorination of a operating cooling system depends upon the maintenance of a biocidal concentration of chlorine in the system for sufficient time to reach the whole microbiological population of the system. Whilst there are a number of surfactants, penetrants and bio-dispersants available to help in process, the basic problem of maintaining relatively high chlorine levels in a evaporating system remains. Chlorine must be dosed throughout the duration of the process in order to compensate for losses via two main routes. Chlorine is lost via the bleed in a predictable way, but the rate of evaporative stripping of chlorine from an active cooling tower varies with water temperature, pH and chlorine level.

We cannot, therefore, make quantitative predictions of rate of loss and so frequent testing and adjustment of chlorine level must be carried out during the process.

Chlorination would normally be preceded by one of the cleaning procedures and so the system water would be in a unconcentrated condition with a pH of 7-8. If not, then the system should be bled heavily or acid dosed so that the pH value falls below 8.0. Chlorinating solution calculated to yield 15 mg/l of chlorine should be added to the system. After a suitable time, the system water should be tested for free chlorine content and further chlorine added as necessary to yield 5-15 mg/l of effective chlorine, with due allowance for pH. Regular testing and replenishment of chlorine should continue until the system has held not less than 5 mg/l of free chlorine for at least 5 hours total. The system may then continue in normal service, the chlorine level being allowed to decay naturally.

1.2 ALTERNATIVES TO CHLORINE

There are a number of alternative disinfecting agents which may be considered instead of chlorine, offering benefits such as reduced corrosiveness or safer handling. Chlorine dioxide solutions, peroxides, ozone and bromine, are typical alternatives. Their use is permitted within the current guidelines, provided they can be shown to as effective as chlorine.

CLEANING OF EVAPORATIVE COOLING SYSTEM (PART-I)

1.1 INTRODUCTION

It is desirable to maintain cooling systems in a clean condition in the interest of effective heat transfer, efficient pumping and minimisation of under deposit corrosion but the importance of cleaning as a precursor to successful disinfection, particularly chlorination, has become paramount. Wetted surfaces, fouled with the kind of corrosion, scale or biomass deposits which may be generated within water systems, provide an environment free from thermal or chemical disturbance. Within this environment, microorganisms are free to

Completion of the process is detected by the visual inspection of the tower and the inability to achieve calcium balance excesses at pH values progressively reduced to 6.5. Although the inhibitor is effective at pH 6.5, corrosion rates will be increased so the system should then be chlorinated if required and returned to normal operation as soon as possible.

1.4.3. ON-LINE ACID CLEANING (SMALLER VOLUME SYSTEMS)

This is an effective method for rapidly removing acid soluble deposits from all wetted areas of a cooling system. Its use is restricted to smaller system (eg with pipe work of less than 300 mm diameter) in which the necessary concentration of acid can be rapidly achieved and with short holding times such that the spent acid can be displaced quickly from the system by make-up and bleed whilst maintaining normal cooling service. Metal skin temperatures are less than 90°C.

Due consideration should be given to the acid action on materials of construction (also avoid mixing acids with chlorine release agents). Arrangements must be possible for the safe, approved disposal of the acidic bleed and spent acid. Since, in all important respects, this procedure is the same as an off-line acid clean, the hazards to plant and personnel are the same. It should only be undertaken by properly trained, equipped and supervised chemical cleaning operators.

The system pipe work and functional components must be checked to ensure their integrity and condition is such that containment of the acidic solutions can be assured, especially when the pipework traverses areas of high damage sensitivity such as ceiling voids above computer suites or populated offices. In systems of this nature, the risks may well be unacceptable. It should be noted that even when strongly acidic solvents are in use, quite large pieces of undissolved debris may be released , particularly from the tower, and cause temporary flow restrictions until broken down by chemical dissolution or mechanical attrition. In extreme cases it may be necessary to physically remove large pieces of scale from pond exit strainers in order to maintain adequate flow of cooling water.

1.4.4. FLOCCULANT CLEANING

These can be effective for the removal of various non-scale deposits of water borne or air borne particulate solids such as iron oxides or hydroxides, silica, clays, soils and other organic decay products. The chosen programme may need to be run for several months.

The process relies upon the conversion of physically bound particulate deposits into more loosely associated mobile flocs, by physico-chemical interaction with medium or high molecular weight organic polyelectrolytes. Its success will depend upon product selection and the hydrodynamic characteristics of the system.

Because turbulent energy is required to bring about the necessary interactions for the resuspension of deposited material, deposit removal will be best in high velocity areas. Indeed, special arrangements for providing increased flows may be necessary to uplift deposits in low velocity areas of the plant. Inevitably, as with any on-line cleaning process, large increases in suspended solids are a feature of the method and a suitable strategy for their removal must be available.

Whilst the monitoring of a flocculant clean-up in a once-through cooling system is a simple matter of comparing suspended solids in the influent and effluent streams, the situation in a recirculating system can be a little more complicated. Cleaner water and reduction of suspended solids in the recirculating water alone are unreliable indicators of success and additional observations such as heat transfer measurement or pressure drop across critical heat exchangers, are the best guide to successful completion of the process.

SHUTDOWN PROTECTION FOR PIPEWORK AND PLANT

INTRODUCTION

When the plant is shutdown, corrosion and general deterioration of pipework and equipment may occur, due to insufficient concentrations of inhibitors and biocides being available for maintenance of protective films. Biological activity may increase, with the accompanying possibility of slime deposits, beneath which corrosion cells may become active leading to severe localised metal loss.

The combination of corrosion products and slime may result in poor heat exchange, and corrosion may continue beneath deposits even when the plant is restarted, due to the difficulty in stifling the corrosion that has commenced. It is recognized that often it is not possible to protect individual items of equipment fully, but whenever possible action should be taken to minimise the harmful effects that can occur. It should also be borne in mind that prolonged isolation of equipment in cold weather may lead to frost damage.

Current guidelines recommended that idle or shut down evaporative cooling plant is properly maintained and cleaned, and disinfected immediately before reuse.

1. METHODS OF PROTECTION

1.1. DRAINAGE

For economic reasons, it may be considered beneficial to drain systems completely when not in use, eg. air conditioning plant. However, there is potential for corrosion as well as the need for system sterilization prior to start-up. It is unlikely that drained systems will be completely dry and the areas which remain wet will support (sometimes considerable) bacteria growth which will have to be dealt with prior to re-

commissioning. If a pre-start up sterilization cannot be assured it will be preferable to leave the system with its associated water treatment on line and run the pumps periodically (minimum weekly.

1.2. CHEMICAL PROTECTION

Dosage and circulation of a high level of both corrosion inhibitor and biocide will normally give good protection of long periods of shutdown.

The system should be run at least once per week to ensure adequate circulation of water and treatment through all parts of the system. This means of protection is often particularly acceptable for small systems or sections of a larger system where drainage is not a practical alternative.

It is recommended that the suppliers of the treatment are consulted prior to a decision being made on the method to be adopted.

1.3. FROST PROTECTION

In cold weather conditions, serious consideration must be given to the prevention of frost damage. In these cases it may be possible to maintain a slow circulation of water through the system, especially if sufficient heat can be introduced to maintain the temperature above freezing point. The fans on the cooling tower should be shut off, and the tower cells by-passed where possible, to minimise heat loss.

SEWAGE EFFLUENT AS COOLING WATER MAKE-UP

INTRODUCTION

The high cost and scarcity of better quality water may dictate the necessity to consider the utilisation of sewage effluent as a source of make-up for cooling water systems. Such water may be used satisfactorily provided that it is adequately treated to avoid operating problems such as deposits, corrosion and organic growths. The treatment may be complicated and expensive to meet these requirements and it is therefore essential to evaluate these in comparison with the cost of alternative supplies.

Consideration must be given to reliability of supply, changes in effluent composition, equipment and operator reliability, and the need for treatment consistency. Another factor is the effect of storm loadings that may cause untreated sewage to pass to the plant outlet. Varied and possibly unacceptable constituents may also be discharged to sewage systems from the industrial users that the system serves. Consideration should also be given to the potential health hazards that could be associated with the use of sewage effluent.

Sewage may contain both Domestic waste and Industrial contamination. It must first have been treated by the conventional processes of primary sedimentation, trickling filtration and humus separation or an activated sludge process to remove the main contaminants before its reuse can be considered. Normally these stages will have been undertaken by a water company before the water becomes available for use. Suspended solids, BOD (Biochemical Oxygen Demand) and pathogenic organisms will be reduced to acceptable levels by these means.

1. CONTROL MONITORING

As make-up water derived from sewage effluent can be variable in nature and unpredictable in quality, it is essential that both treatment and monitoring for composition, corrosion and microbiological content and control are practiced. Failure to do so will inevitably lead to serious system problems, with likely performance loss and high maintenance costs. With so many variables present it may need an extended period of experimentation, before all actual or potential problems are brought under control and effective corrosion and fouling protection of the heat exchange equipment is obtained.

2. ECONOMICS

Costs for successful treatment of sewage effluent will inevitably be high. These are in addition to the charge which is often levied for effluent and the capital cost of plant and equipment to treat such water. These costs may well make the use of sewage prohibitively expensive in comparison to those of an alternative supply.

The use of sewage effluent is technically possible but, before such a course is embarked upon, very careful consideration should be given to the possible problems and costs that may be encountered.

CONCENTRATION & CONCENTRATION FACTOR

The term concentration is used in cooling water technology in two ways :

1. As in standard chemical parlance it is used to indicate the amount of substance present in solution or other medium, for example, 200 mg/l sodium chloride as solution in water or 2 g/m^3 ammonia in air.

2. The term concentration is also sometimes used in the sense of concentrating effect to describe the accumulation of dissolved solids in a cooling system subject to evaporation.

If, for example, 1 litre of water containing 230 mg/l dissolved solids is reduced by evaporation to 500 ml and no precipitation takes place, the solids content will increase to 460 mg/l, ie. It concentrates by a factor of 2.0. If the water were reduced in volume still further to 250 ml the solids content would increase to 920 mg/l, i.e. it would concentrate by a factor of 4. The expression ""t concentrates twice" is ambiguous and should be avoided and the term "concentration factor", or "Cycle of concentration" should be used.

1. CONCENTRATION FACTOR

Evaporative cooling systems are subject to two kinds of loss

a) Evaporative Loss

b) All other water loss, collectively known as wastage.

This wastage can include leakage, deliberate removal for other applications and losses in droplet form (drift and windage). In most systems, extra water must be wasted to limit the concentration factor, this is known as bleed or blowdown.

$$\text{Concentration factor (n)} = \frac{\text{Wastage + evaporative loss (E)}}{\text{Wastage}}$$

$$\text{Wastage} = \frac{E}{n-1}$$

$$\text{Makeup} = \text{wastage + evaporative loss} = E + \frac{E}{n-1}$$

The maximum value of **(n)** which can be permitted in any particular cooling system depends on several factors including maximum water temperature, composition of water supply, temperature drop in tower, nature of chemicals applied and residence time.

In systems where the evaporative loss is not known, an approximate value can be obtained from the temperature drop in the cooling tower. Irrespective of the temperature of operation the evaporative loss for each 10^0C temperature drop in the tower is 1.8% of the circulation rate.

EXAMPLE :-

To determine the bleed for a given concentration factor :-

Desired concentration factor : 1.8

Circulation rate : 1000 M^3/hr

Temperature Drop : 15 ^{0}C

Leakage and drift : 20 M^3/hr (measured by determining make-up rate without bleed)

$$\text{Evaporation rate} = 1.8\% \times 1000 \times \frac{15}{10} = 27\ M^3/hr$$

$$\text{Wastage required} = \frac{E}{n-1} = \frac{27}{1.8-1} = \frac{27}{0.8} = 33.75\ M^3/hr$$

$$\text{Make-up required} = \frac{E + E}{n-1} = 27 + 33.75 = 60.75\ M^3/hr$$

Bleed required = 33.75 – 20 = 13.75 M^3/hr

WHAT IS THE SIGNIFICANCE AND INTERPRETATION OF MICROBIOLOGICAL ANALYSIS?

INTRODUCTION

It is important that microbiological fouling should not be treated as a problem totally separate from others encountered in water systems. To illustrate some inter-relationships, the products of scale and corrosion may provide an ideal habitat for the growth and reproduction of bacteria, while the bacteria themselves could well be the major cause of corrosion. To establish microbiological control of a system, it must initially be clean and the treatment programme must take all aspects in account.

Many different types of chemicals are now available for the control of microbiological fouling within cooling water systems. Each of the general types of compounds used have varying degrees of activity against micro-

1.1. VALUE OF THE TOTAL BACTERIAL COUNT

This refers to the total aerobic bacteria found in the bulk water. Historical counts on a particular system are needed to gain insight into the total count data. Nutrient level, temperature and experience gained in other systems should be considered to assess the degree of control required and the type of biocide and programme best suited to a particular system.

A single microbiological analysis only represents conditions at the time of sampling. Probably of more importance is the trend in microbiological activity. Results ideally should be plotted graphically to determine the minimum effective dosage of the biocide in the system, and to establish the minimum frequency of addition needed to maintain control.

Continual dosage of the same type of non-oxidising biocide to a population of micro-organisms will consistently kill a very high percentage, but it is possible that some organisms will be resistant to a specific biocide and others may develop a resistance. The resistant organisms or strains will than multiply rapidly in the absence of competition and a different biocide will then be required. Therefore, it is good practice to institute a programme of alternating different biocides.

All microbiological problems associated with cooling systems should be investigated by specialists, so that the benefit of their experience may be applied in establishing the needs of individual plants.

1.3. CORROSION ATTRIBUTABLE TO SULPHATE-REDUCING BACTERIA HAS THREE MAIN CHARACTERISTICS

A) It occurs in anaerobic environments in the presence of water. Encrustations or 'tubercles' on the metal harbour sulphate-reducing bacteria and provide suitable anaerobic conditions for corrosion. When subjected to intermittent aerobic/ anaerobic conditions, iron objects often corrode faster than under constant anaerobic conditions. This is probably due to secondary corrosive reactions resulting from the activities of these bacteria.

B) The corroded metal is pitted rather than evenly corroded. The rate of pitting increases with time, indicating that the process is of an autocatalytic character. Corroded pipes tend, therefore, to perforate rather than desintegrate.

C) Cast-iron leaves a carbon residue at the site of corrosion, and the metal becomes 'graphitised'. Both iron and steel form a corrosion product containing much iron sulphide.

While these limits may be acceptable in certain plants, different limits (higher or lower values for slime forming and total bacterial count) may be needed on other plants. In all cases, however, there should be an absence of sulphate reducing bacteria.

1.3. MICROBIOLOGICAL MONITORING – Use of Dip Slides.

Dip slides are used as a guide to on-site testing for the level of activity of micro-organisms within cooling systems. Specific record sheets for dip slide results can be laid out in graphical form. Such progressive graphical records will indicate clearly trends within a given system that will be apparent at a glance.

It cannot be emphasised too strongly that dip slides will only show trends in micro-organisms activity. The results cannot be taken as specific scientific quantitative findings such as would be obtained by TVC results obtained in a microbiological laboratory.

There is a unfortunate tendency to over-react to high counts obtained from dip slide results.

The following procedures should be observed.

1. The sampling procedure must be carried out in such a way that no external contamination can occur and the sample obtained is representative of the system water.

2. To ensure reproducible results an incubator set between 30-35^{0}C must be used. Always allow the same time period for incubation, eg. note a reading after 24 hours, then again after 48 hours if there is a significant change.

3. Log the results on the weekly graph sheet, note any trends, and take another dip slide to check the results if a high reading has been obtained. Further high readings will require checking by submitting a TVC sample to a microbiological laboratory. Remedial action, as dictated by site protocol may be required.

4. Boxes of dip slides are date stamped and only those within a given date should be used. Results may be unreliable if old or out of date slides are used.

The limitations of dip slides can be summarised :

a) Providing the time / temperature relationship is constant, the slide results are mainly reproduce but the method does have inherent difficulties.

b) The small area of agar on the slide causes crowding of the colonies. Some may develop with no colour and thus be overlooked.

c) Surface active agents may be absorbed which may prevent the development of many colonies, leading to inaccurate results.

d) Only the organisms capable of growing on the medium used and at the temperature of incubation chosen will develop and a number of dead organisms will go unrecognised.

e) Dip slides can not give any indication of the presence of Legionella, so if dip slides results show NIL or very low counts, the absence of Legionella cannot be assumed.

f) Dip slides will not give any indication of specific micro-organism activity.

IS YOUR COOLING WATER TREATMENT PROGRAMS ENVIRONMENTALLY SAFE ?

Although Water Treatment technology has made large advances over the past 60 years, the objectives of successful treatment programme have remained the same: extend equipment life and maintain efficient heat transfer. This has been accomplished by minimizing corrosion of system metallurgy as well as keeping metal surfaces free from deposition. From a historical perspective, even the earliest Cooling Water Treatment programmes have addresses these concerns by the incorporation of concerns inhibitors and deposit control agents. Examples of traditional treatment programmes are as follows: - Polyphosphates/Deposit control agents (natural products). - Chromate - based - Zinc-based

Scanning of the recent work on cooling water treatment reveals that the published literature has been mainly dedicated to the search for environmentally safe corrosion and scale inhibitors. The present research deals with types, structure, efficiency, biodegradability and advantages of new compounds "mixtures". green chemistry and green chemicals are defined and the approach adapted in finding such compounds and the method of evaluation are highlighted. A promising approach is represented by the combination of biodegradable polymers and environmentally safe amounts of phosphorous and chromium. New inhibitors other than the green ones, and the recent work on ozone have been considered as well. Guidelines for the future work on water treatment chemicals are being redefined.

Cooling towers are used by office buildings and manufacturing plants throughout the India to dissipate waste heat from air conditioning, industrial and power generation processes. Recirculating water transfer thermal energy from the building or industrial process to the atmosphere. Atmosphere air blown through the cooling tower carries away the heat.

Environmental problems arise when water escapes from the system in the form of droplets. Such water droplets carry with them various chemicals that are used in the system. Some of these chemicals are environmentally harmful. Hexavalent chromium is the one that is of the most concern and warrants immediate attention.

Hexavalent chromium-based ("chrome") compounds are among the most efficient and cheapest corrosion inhibitors available. The trouble is, hexavalent chromium is a suspected carcinogen, and is highly toxic. Chrome emissions from cooling towers in New Delhi alone could cause as many as 700 cancer cases over a 70 year exposure period.

Indian Government has banned the use of hexavalent chromium water treatment chemicals in open water circulating systems that are potentially capable of emitting respirable hexavalent chrome. This prohibition is expected to reduce the risk of cancer cases due to cooling tower emissions to virtually zero. Additionally, elimination of hexavalent chromium-based treatment chemicals will eliminate the amount of hazardous and toxic wastes discarded through blowdown.

Non-chromate chemicals may also have some adverse impacts on the environment. For example, while zinc based chemicals are particularly dangerous to humans, they are highly toxic to marine life. Similarly, phosphate discharges into lakes and ponds may cause excessive algal growth leading to eutrophication problems. But in comparison to the highly toxic chromate inhibitors, the substitute chemicals are relatively innocuous and do not present the same environmental problems that chromates do. Nevertheless, the impact of substitute chemicals on the environment must be carefully analyzed before actually using them.

It is encouraging to note that , 85% of the cooling towers operating in India had already changed to non-chromate systems. The remaining 15%, however, have the potential to cause more cancer cases in the years ahead if they are not modified.

Currently, the best possible solution to the chromate problems appears to be replacement with non-chromate chemicals. However, in view of the potential hazards of many of the alternate chemicals, it may be wise to eliminate or reduce the emission of any treatment chemicals into the environment. This could be accomplished by:

a) Makeup water pretreatment. Pretreatment of makeup water to cooling towers reduces the chemical treatment requirements for scale and corrosion control and can increase the number of times cooling water may be recycled before blowdown. Pretreatment reduces dissolved solids in the makeup water through precipitation and flocculation, softening and ion-exchange. Suspended solids are removed by clarification and filtration. Pretreatment may not be economical for "comfort" cooling towers those used in office building air conditioning systems) but is advantageous for large industrial cooling towers.