Water Management in Thermal Power Plants

Dr. PRADEEP JAIN
(EX-GM, NTPC_NETRA)

DIRECTOR_RA CHEMTECH PRIVATE LIMITED, NEW DELHI

Email_pkjain3621@gmail.com

COOLING WATER

The most important uses of cooling water in power generation includes

1. Condensing of turbine exhaust steam in condenser
2. Auxiliary cooling water uses in process
3. Protecting high pressure pump bearings by cooling.

Cooling water chemistry control is very critical in preventing Corrosion, Scale and Fouling problems.

Sources of water

- Surface water

\- Lake, pond/reservoir, river, canal

- Ground water

\- Bore wells

- Sea water

\- Including Brackish water (Back sea water)

Types of Surface Water use as make up water in CW system

- Raw Water
- Clarified Water
- Filtered Water
- Soft Water

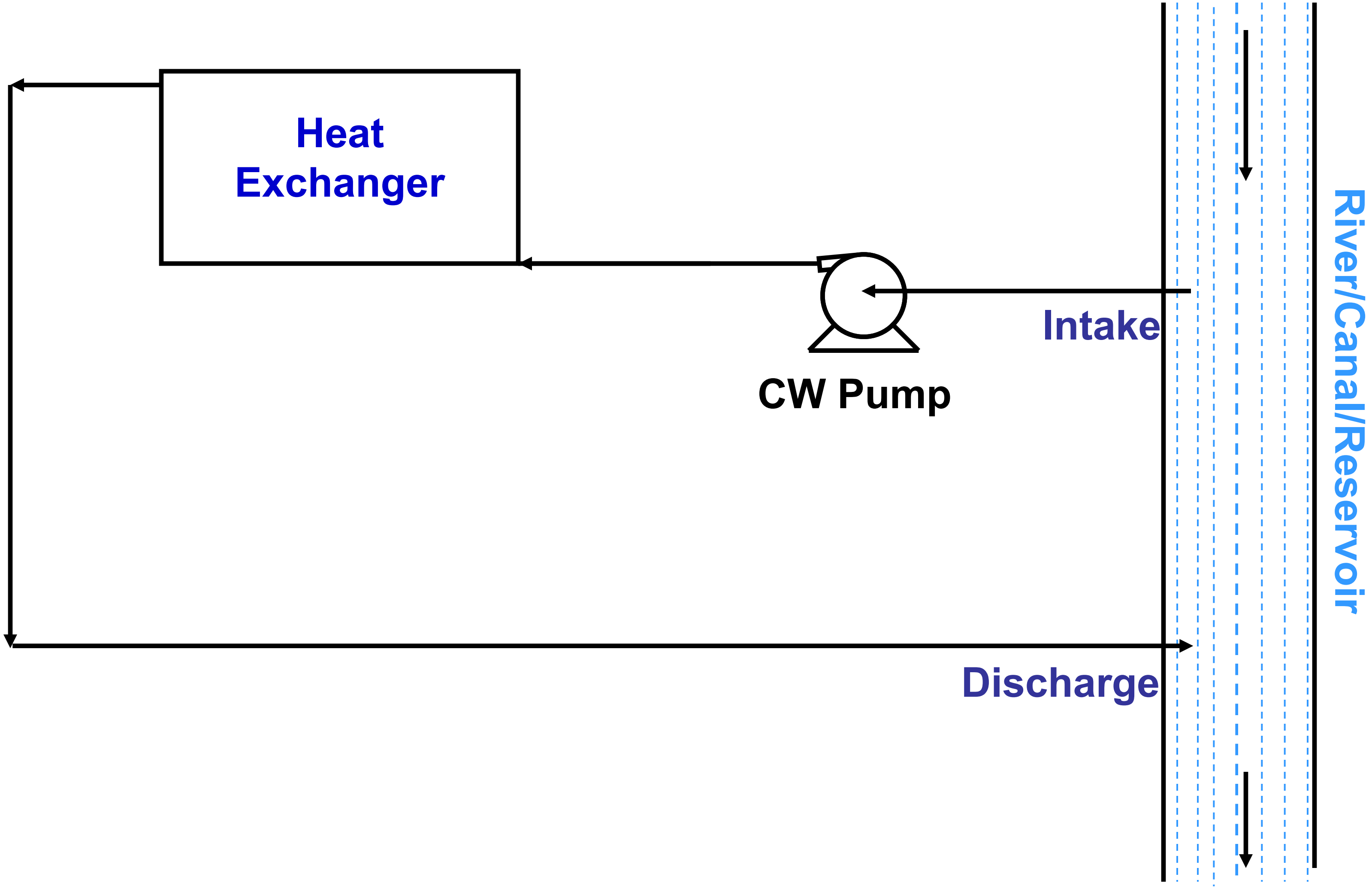
Types of cooling water system

1. Once-through
2. Closed Re-circulating
3. Open Re-circulating (Evaporative cooling towers)

Once Through System

- Water goes form one pass of heat exchanger and discharged from other pass to the source.
- Large quantity of water is needed.
- Once-through system have advantage, it will not allow cooling water to concentrate, thus reducing scaling and corrosion potential.
- Water is returned to source at higher temperature, thus cause thermal and chemical pollution of water bodies.
- Highly prone to biological fouling.

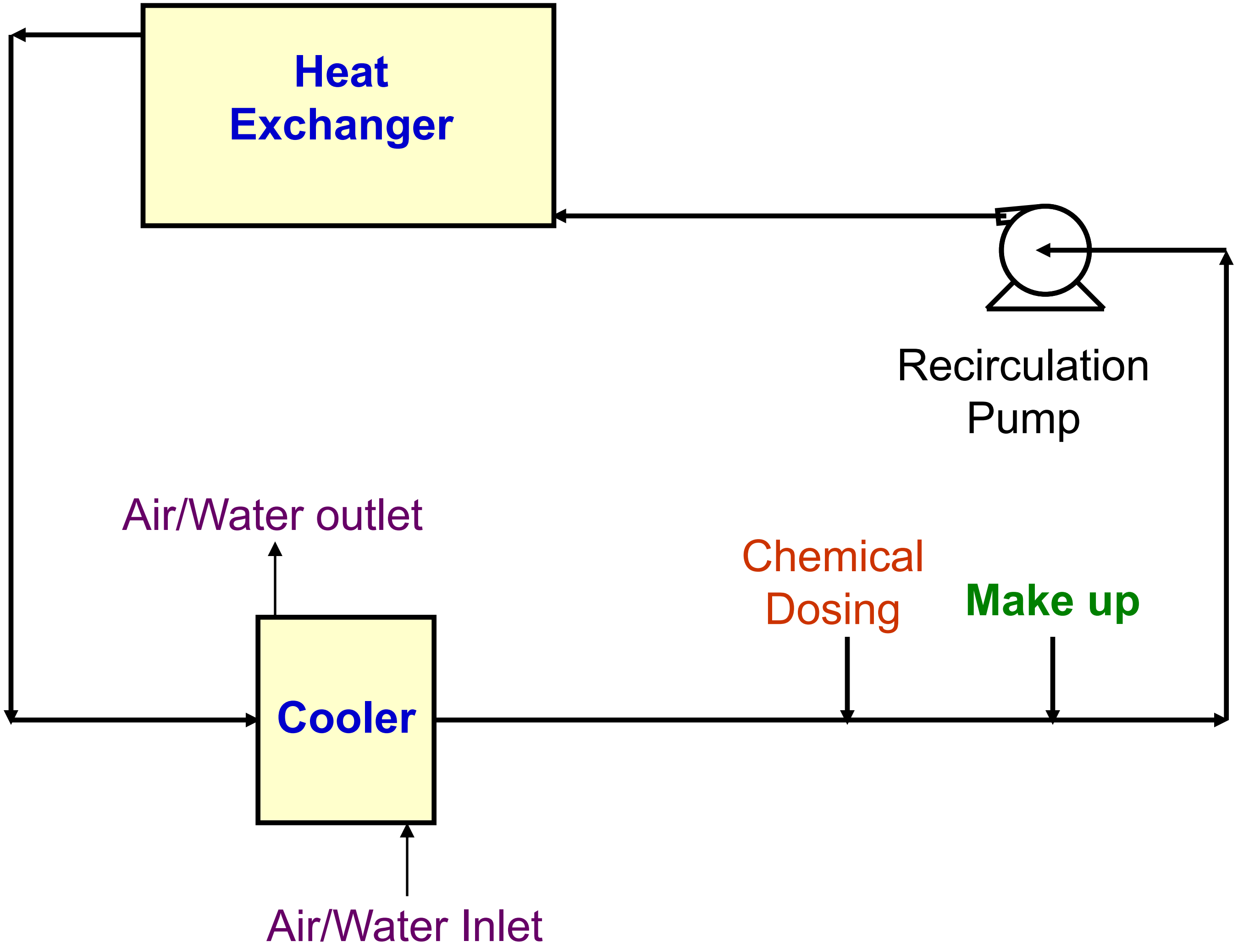
Once Through System



Closed Recirculating System

- Water circulates in a closed cycle, completely confined within the system and heat exchangers.
- Alternate cooling and heating without air contact
- Heat absorbed by the water in closed system is transferred by a water to water exchange to the recirculating water of an open recirculating system from which the heat can be lost to atmosphere.
- Example:- Electric generators and Chilled water systems etc. which is having secondary cooling water system by plate type heat exchangers.

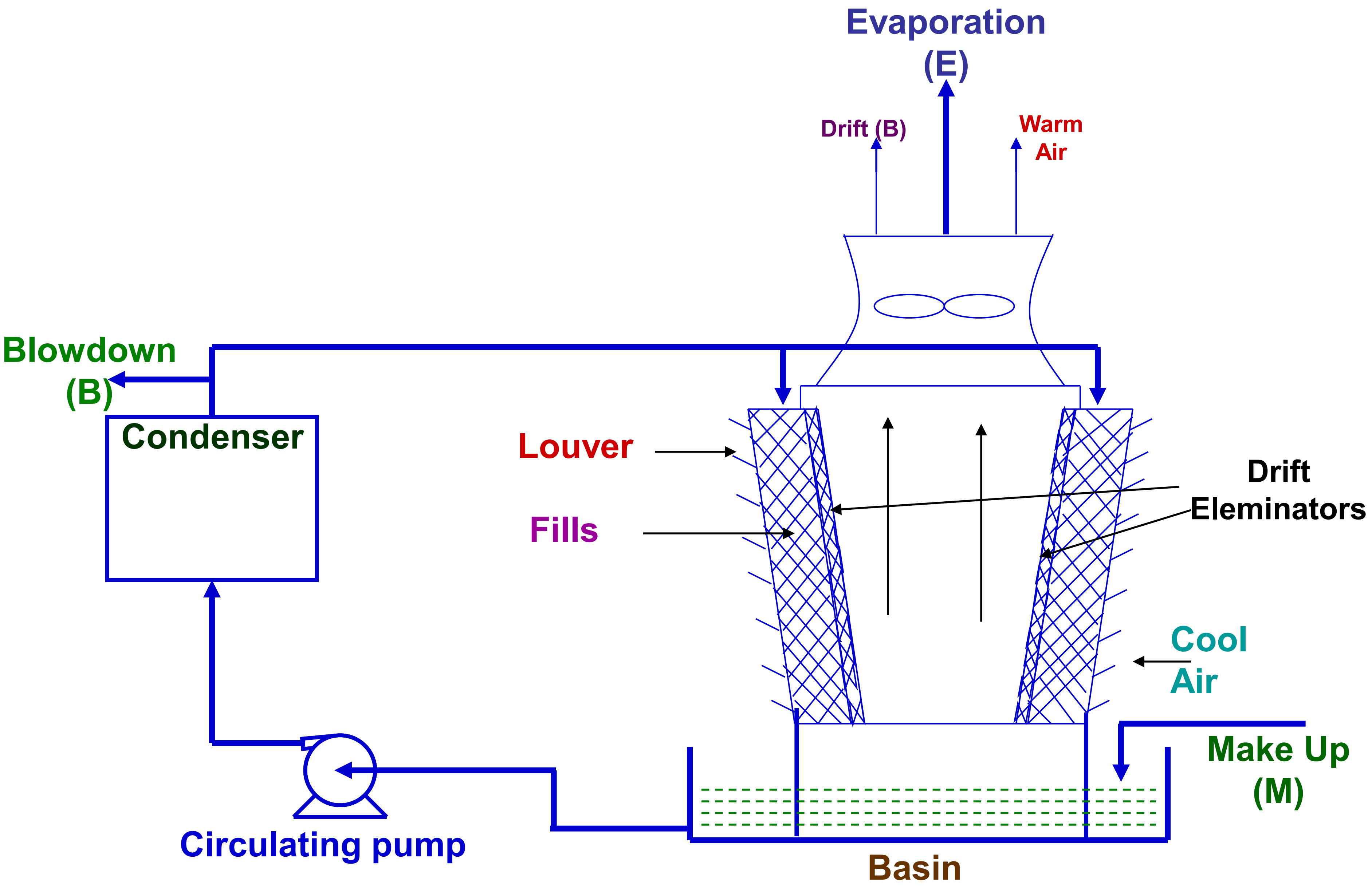
Closed Re-circulating System



Open Recirculating (Evaporative cooling Towers)

- Water circulates through the condenser or heat exchanger to a cooling tower and then returned to exchanger after cooling.
- Cooling of water is by evaporation process, water loss by evaporation and drift.
- The evaporated water is very pure and the minerals are left behind to concentrate.
- Used in power plants, chemical, petrochemical, steel, paper industries and all types of processing plants.

Open Recirculating System

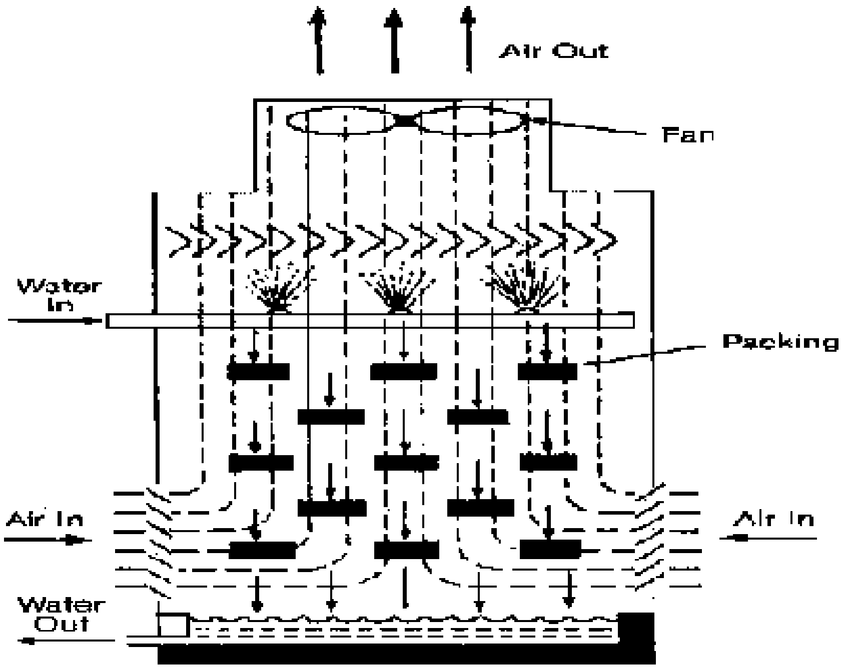


Types of Cooling Towers

- FORCED / INDUCED DRAFT COOLING TOWERS
- NATURAL DRAFT COOLING TOWERS

FORCED / INDUCED DRAFT COOLING TOWERS

FIGURE 11.7
Counterflow Mechanical Draft Tower



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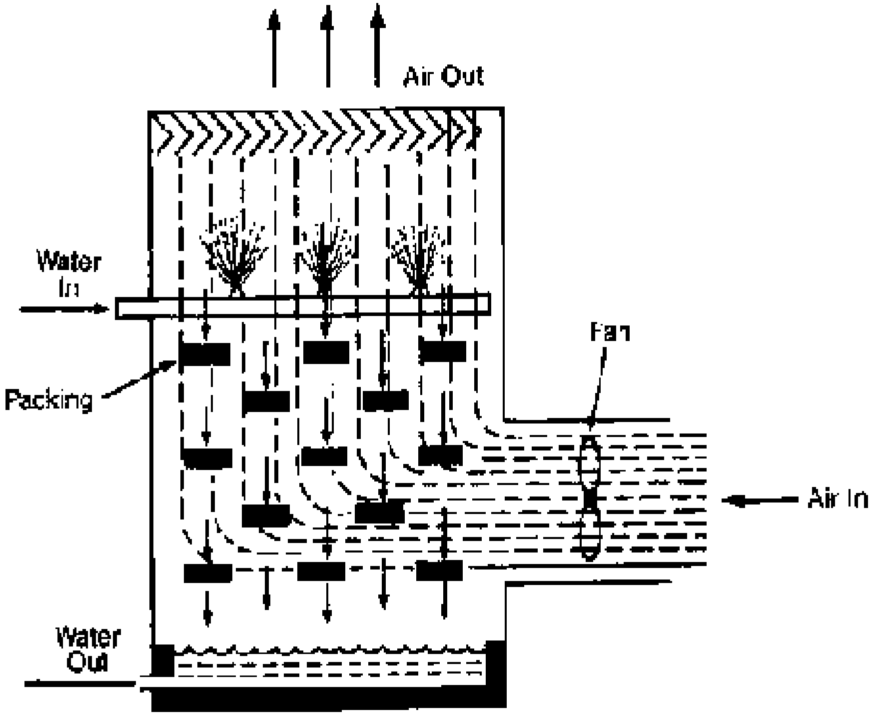
Induced Draft Tower



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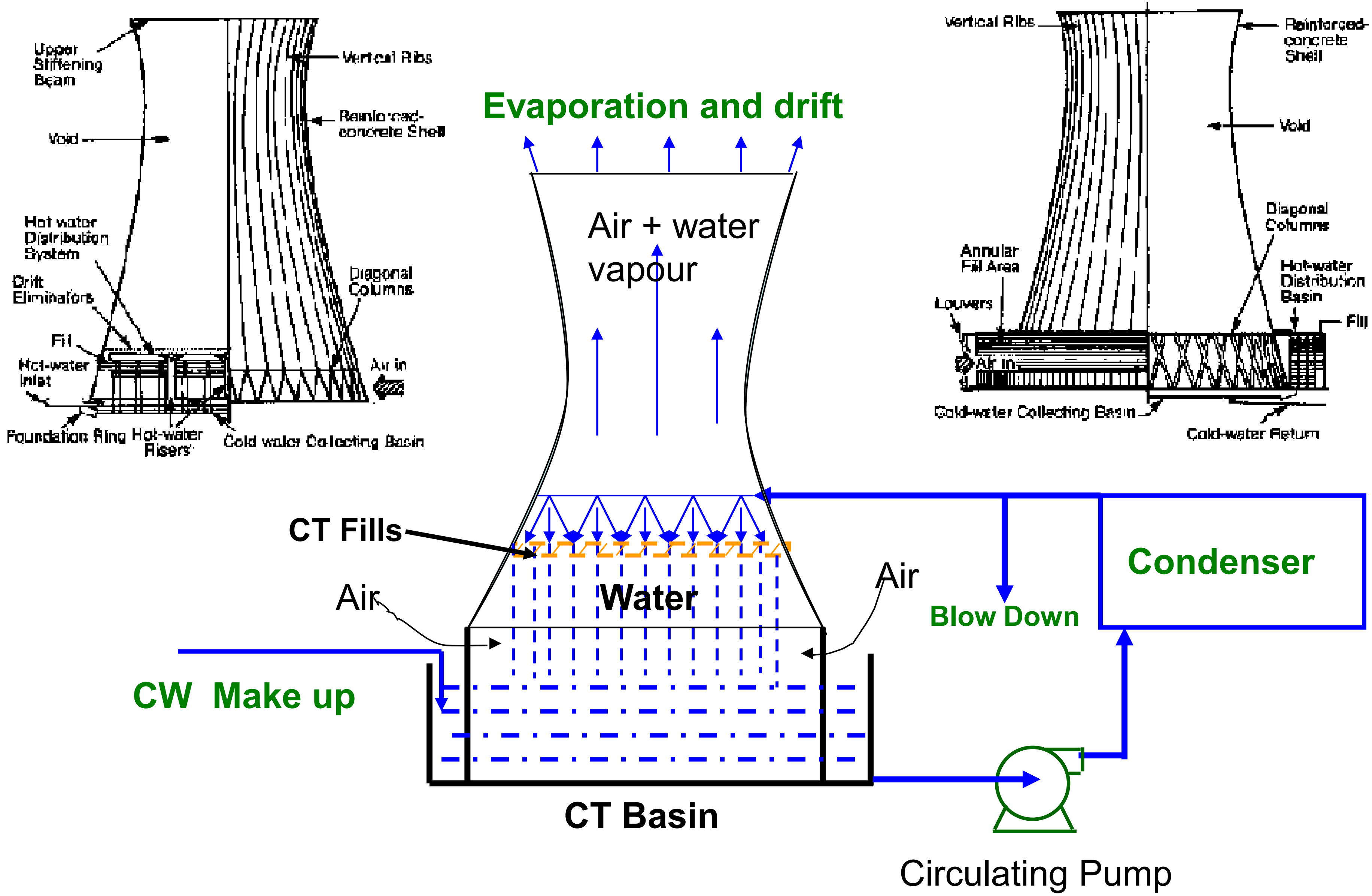
Forced Draft Tower

Natural Draft Cooling Tower

Counterflow

Crossflow



TERMS ASSOCIATED WITH COOLING TOWER

Evaporation : Approx. amount of evaporation that occurs in a cooling tower can be calculated using the following formula.

E = (Cr X DT) / 1000

E = Evaporation rate, M3/hr

Cr = Recirculation rate of cooling tower

DT = Temperature diff. (^{o}F) between hot and cool circulating water

As air rises inside the **tower**, it receives the latent heat of vaporization from the **water**, and thus the **water** is cooled. As a rule of thumb, for every 10°F (5.5°C) of **water cooling**, 1% total mass of **water** (Circulation Flow Rate) is lost due to **evaporation.**

TERMS ASSOCIATED WITH COOLING TOWER

Drift (D) : Drift is a form of blow down that occurs due to entrainment of water droplets in the air leaving the cooling tower. Drift typically ranges from about 0.05% to 0.3% of the recirculation rate depending upon the type and efficiency of the cooling tower.

Make up (MU): Water added to circulating water system to replace water lost from the system by evaporation, drift, blown down, and leakages.

TERMS ASSOCIATED WITH COOLING TOWER

Cycle of concentration (COC)

Number of times the circulating water is concentrated in cooling tower is known as Cycle of conc. The maximum (COC) depends upon the effectiveness of corrosion and scale inhibitor programs and on the quality of make up water.

Blow Down (BD)

Some water must be continually removed from cooling water system to prevent excessive build up of the dissolved solids. This is known as blow down.

Cooling Water Balance

Evaporation (E), Blow down (BD), Drift (D) and Make Up (MU) constitute the water balance around the cooling tower.

$$\text{COC} = \frac{\text{Cl}^{-} \text{ or } \text{Mg}^{+2} \text{ Conc in BD}}{\text{Cl}^{-} \text{ or } \text{Mg}^{+2} \text{ Conc in MU}}$$

$$\text{BD} + \text{D} = \frac{\text{E}}{\text{C}-1}$$

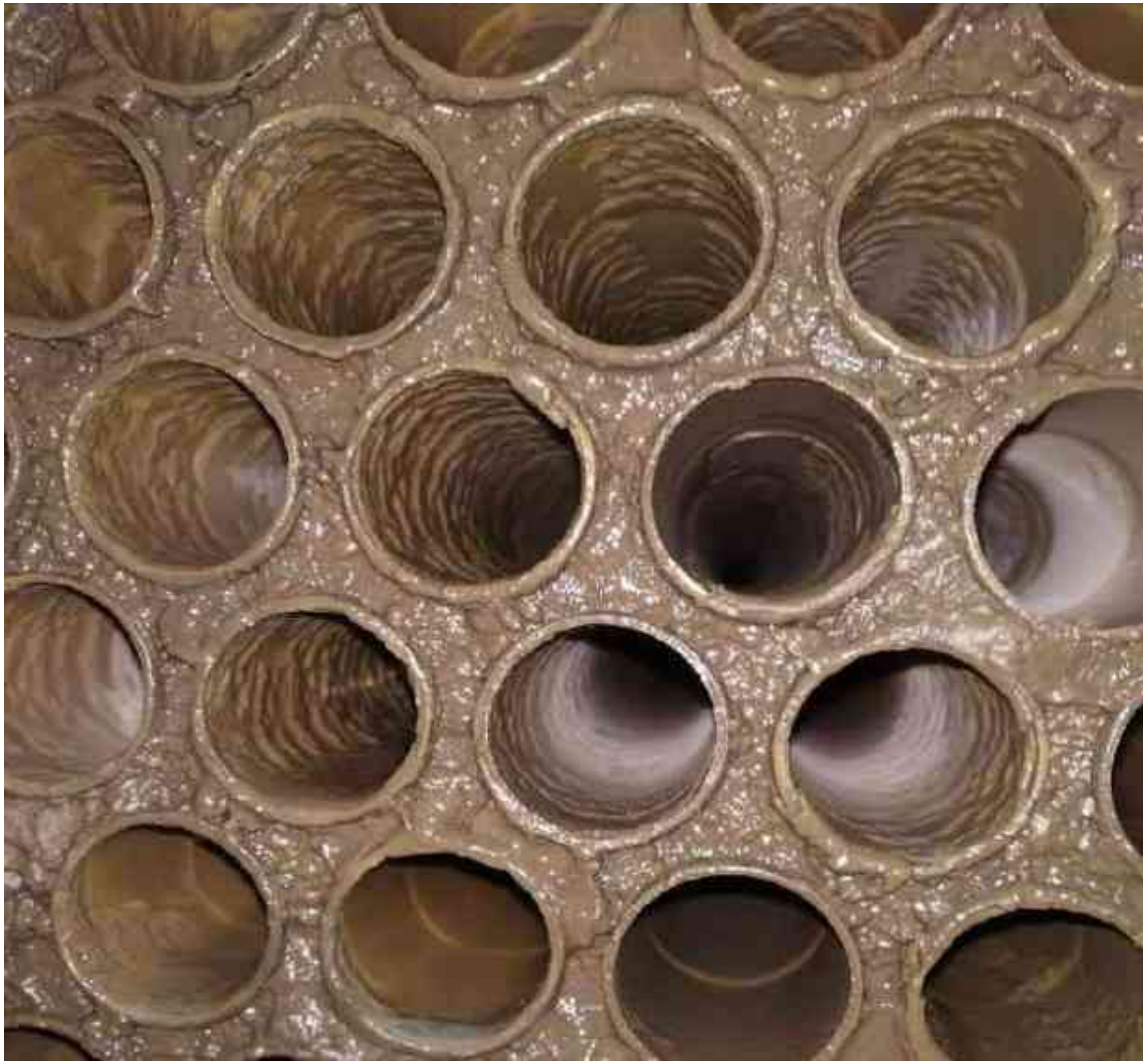
$$\text{MU} = \text{E} + \text{BD} + \text{D}$$

Cooling Water Associated Problems

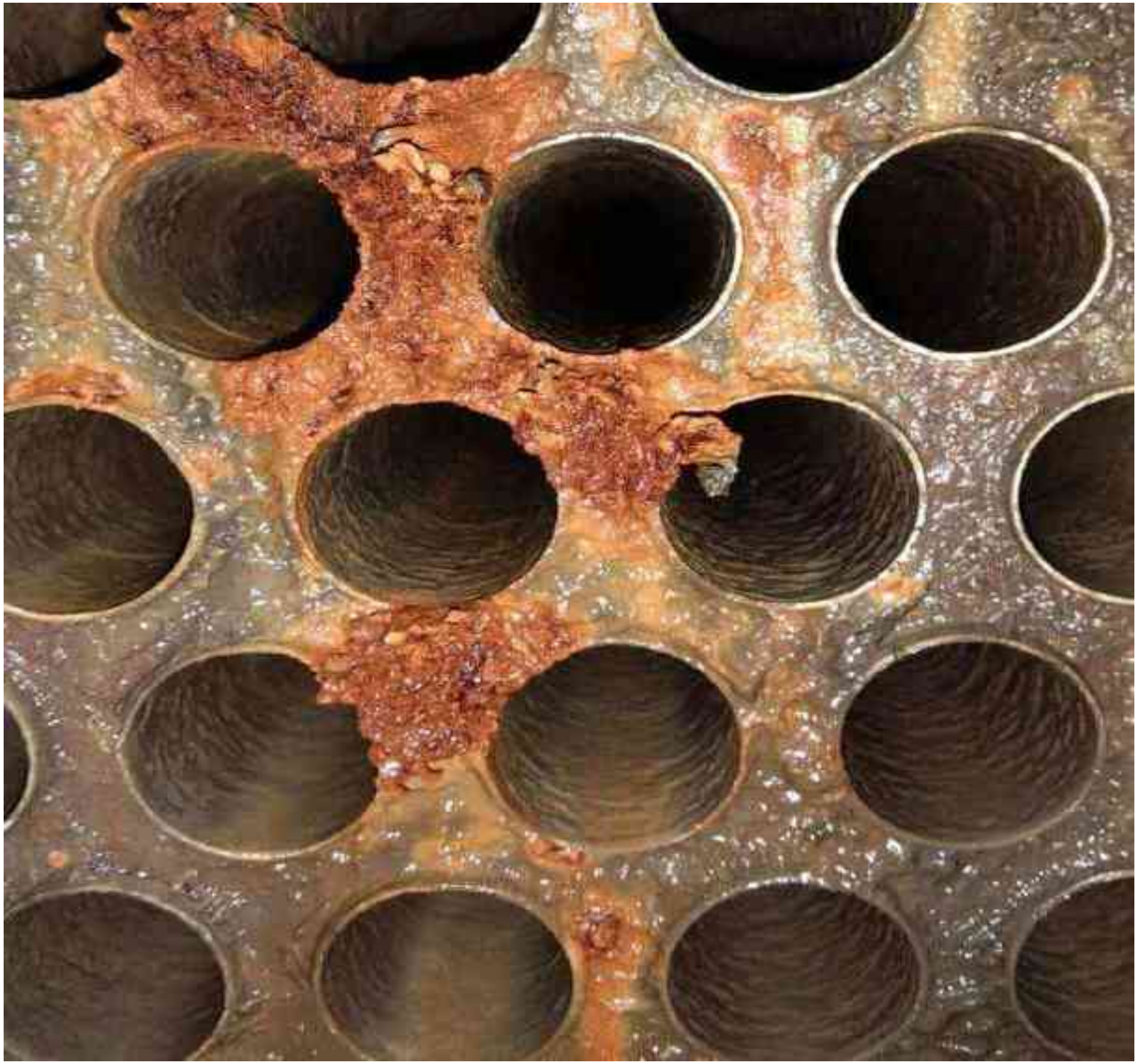
Due to water’s ability to dissolve most substances to some extent, and its ability to support biological life every cooling water system is subjected to potential operational problems. These are:

1. Deposit formation
2. Corrosion
3. Biological deposition and corrosion

Condenser Tube having scale deposition in 110 MW Unit



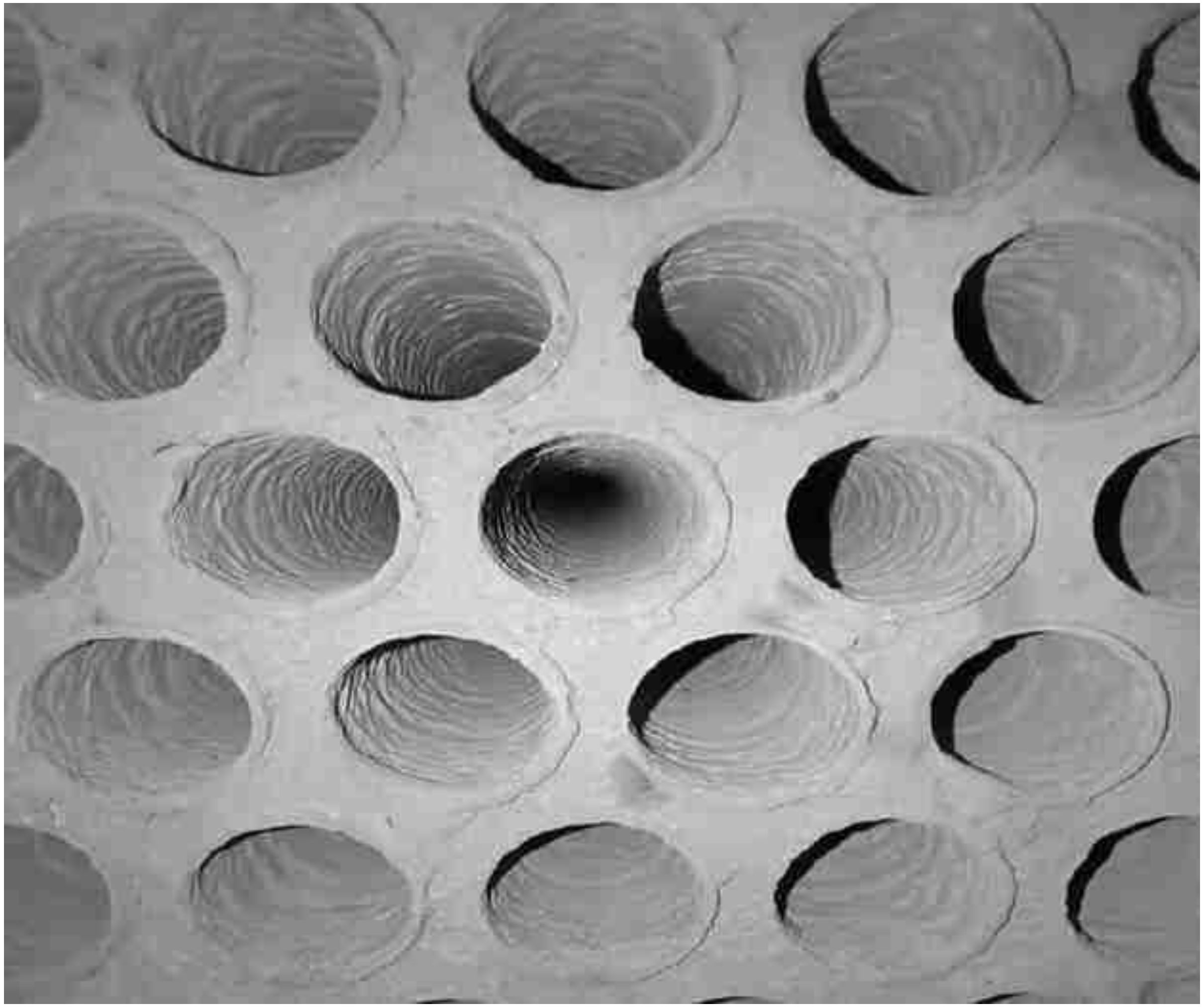
Condenser Tube having scale deposition in 210 MW Unit



Condenser Tube having scale deposition in 250 MW Unit

Condenser Tube having scale deposition in 500 MW Unit

Condenser Tube having scale deposition in 500 MW Unit



Internal surface of condenser tube made of SS-304 showing calcium carbonate deposition

Condenser Tube having clean surfaces in 200 MW Unit

Condenser Tube having scale deposition in 500 MW Unit

Internal surface of condenser tube made of SS-304 showing clean surfaces

Condenser Tube having scale deposition in 500 MW Unit

Internal surface of condenser tube made of SS-304 showing calcium carbonate deposition

Condenser Tube having scale deposition in 500 MW Unit

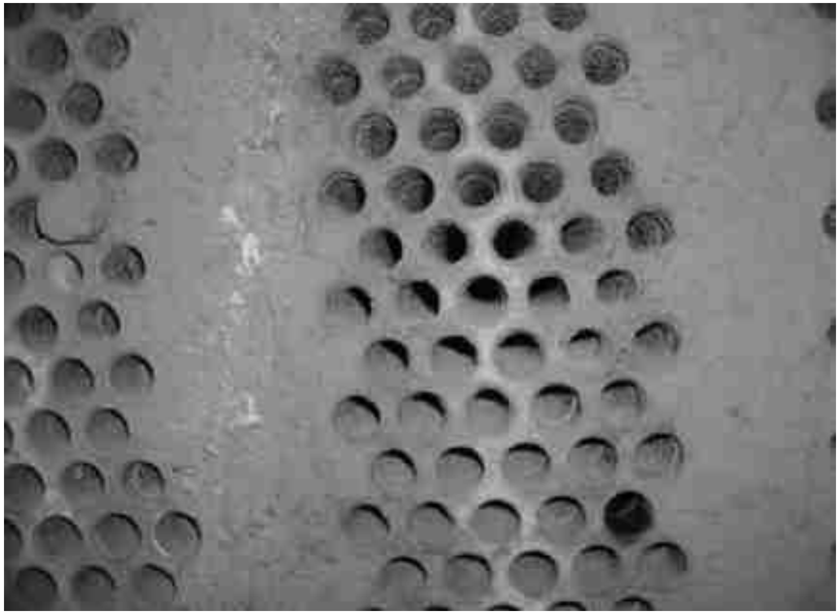
Internal surface of condenser tube made of SS-304 showing calcium carbonate deposition

Condenser Tube having scale deposition in 500 MW Unit

Internal surface of condenser tube made of SS-304 showing calcium carbonate deposition

SCALE DEPOSITION

Due to increase of Cycle Of Concentration, the concentration of the dissolved ions in cooling water increases, solubility of one or more of the constituents is exceeded the solubility product. The compound precipitates and form deposit.



SCALING IN CONDENSER TUBES

SCALING IN COOLER TUBE

Scale forming salts in Cooling Water

Most Common

- Calcium Carbonate
- Calcium Sulphate
- Calcium Phosphate
- Iron oxide
- Silica

Less Frequent

- Magnesium Silicates
- Zinc Phosphate
- Calcium Floride
- Iron Carbonate

Factors Affecting Scale formation

- Water Temperature
- Alkalinity or Acidity
- Concentration of scale forming salts
- Physical Fouling
- Microbiological concentration in CW
- Flow rate of Cooling Water
- Operating Conditions of the Process

Effects of Scale deposition

- Scale forms an insulating barrier and restricts heat transfer thus decreasing cooling efficiency.
- Flow restriction through condenser tubes
- Reduction in condenser vacuum and power generation.
- Reduction in heat rate of cycle.

How to control the Scale formation

There are three basic methods for preventing formation of scale in cooling water system

1. Remove the hardness salts / minerals from the water prior to use.
2. Keep scale-forming constituents in solution
3. Control of COC will not allow impurity to precipitate in the system.

Scale Control

Calcium carbonate is the most common frequently encountered scale in cooling water system. It forms when Calcium and carbonate alkalinity exceed the saturation level and began to precipitate as calcium carbonate.

Langelier Saturation Index (LSI)
Ryzner Stability Index (RSI)
Puckorious (or modified stability) index

These are very useful indices for determining scale and scale tendencies of make up water.

Scale / Corrosion Monitor Index

To predict corrosive or scale forming tendency of water following indices are used.

- Lengelier (or Saturation) Index

LSI = pH - pHs

pHs = (9.3 + A +B) - (C + D)

A -Total Dissolved Solid, ppm

B – Temperature, F

C - Calcium Hardness, ppm

D - Alkalinity of Cooling Water, ppm

CALCULATION OF pHs BY CALCULATOR

- Enter ppm Ca as $CaCO_3$
- Multiply by total alkalinity, ppm as $CaCO_3$
- Take log of the product, store in memory, clear
- Enter water temp. °F
- Multiply by temp. coefficient
  - T < 77 = 0.0142
  - T > 77 = 0.00915
- Add memory to product, store sum memory, clear
- Enter T.D.S. in ppm and take log
- Multiply by 0.10, add constant per temp
  - T< 77°F = 12.65
  - T> 77°F = 12.27
- Substract memory, round off to near by hundredth as pHs
- Lengelier saturation index = pH - pH_s

CALCULATION OF pHs BY CALCULATOR

- Ryzner (or Stability) Index
  RSI = 2pHs – pH

Puckorious (or modified stability) index
PSI = 2pHs – pH_e
($pH_{\mathbf{equilibrium}}$ = 1.465$\log_{\mathbf{(total\ alkalinity)}}$)

LSI - +ve indicates Scaling tendency
LSI - -ve indicates Corrosive tendency
RSI - > 6.0 indicates Corrosive tendency
RSI - < 6.0 indicates Scaling tendency
PSI - > 6.0 indicates Corrosive tendency
PSI - < 6.0 indicates Scaling tendency

Scaling Severity keyed to index

LSI	RSI/PSI	Conditions
3.0	3.0	Extremely severe scaling
2.0	4.0	Very severe
1.0	5.0	Severe
0.5	5.5	Moderate
0.2	5.8	Slight
0.0	6.0	Stable Water
-0.2	6.5	No scaling very slight tendency to dissolve solids
-0.5	7.0	No scaling slight tendency to dissolve solids
-1.0	8.0	No scaling moderate tendency to dissolve solids
-2.0	9.0	No scaling strong tendency to dissolve solids
-3.0	10.0	No scaling very strong tendency to dissolve solids

Limiting COC without Treatment

In re-circulating type of cooling, a definite concentration of scale forming salts are allowed to retain in the system, beyond which salts are likely to precipitate to form scale

Concentration of Calcium in make up water as $CaCO_3$ in ppm	**Cycle of Concentration**
100	**2.0**
150	**1.7**
200	**1.5**
250	**1.3**
300	**1.1**

To attain the above, blowdown of water from the cooling cycle and fresh water is required to be taken into the circuit. Similarly blowdown of CW is required when $CaSO_4$ and Silica values are exceeding 1250 ppm and 125 ppm respectively.

Methods to control the Scale formation

- Softening of Make Up water to remove hardness salts from makeup water.
- Keep scale forming salts in CW system by pH adjustment, Dosing of Polyphosphate.
- Dosing of Organo-Phosphonates as Scale Inhibitors
- Control of Fouling / Bio-fouling
- Limiting Cycle of Concentration to reduce the ionic concentration in CW system
- Periodic Chemical Cleaning of heat exchangers
- Mechanical High Pressure water Jet Cleaning

Softening of Make Up Water

Softening process removes Calcium and Magnesium either by

- Lime soda softening (Faridabad Gas)
- Ion-Exchange process (Dadri Thermal)

$$CaCO_3 + R\text{-}Na = Na_2CO_3 + R_2\text{-}Ca$$

$$MgCO_3 + R\text{-}Na = Na_2CO_3 + R_2\text{-}Mg$$

Softened water upto 5 ppm hardness as $CaCO_3$ is supplied as make up to the CW system. The chances of precipitation of scale is minimized provided alkalinity and TDS of CW do not become very high to affect the scaling index.

Lime softening is not preferred due to high pH of softened water. (Acid dosing required for pH control)

In case of Ion exchange softening (base exchanger) discharge of waste regenerant (brine solution) is problematic as observed in NTPC station.

Scale Control Program

- Acid Feed

  Sulfuric acid addition reduce bicarbonate alkalinity as follows

  $H_2SO_4 + Ca(HCO_3)_2 \longrightarrow CaSO_4 + CO_2 + 2H_2O$

  Alkaline Treatment Method

  Alkaline treatment programs are designed to either keep calcium in solution or to modify the crystalline structure of calcium precipitate so that a sludge like product will form, which can be taken out from the system by blow down.

Scale Control Program

Scale stabilizing chemicals include Polyphosphate and Polyacrylates

Organophosphonates

AMP – Amino tri(methylene) phosphonate

HEDP- 1-hydroxyethylidine-1,1-disphophonic acid)

PBTC – 2-phosphonobutane-1,2,4- tricarboxilic acid

Crystal Modifiers

Copolymers and Terpolymers

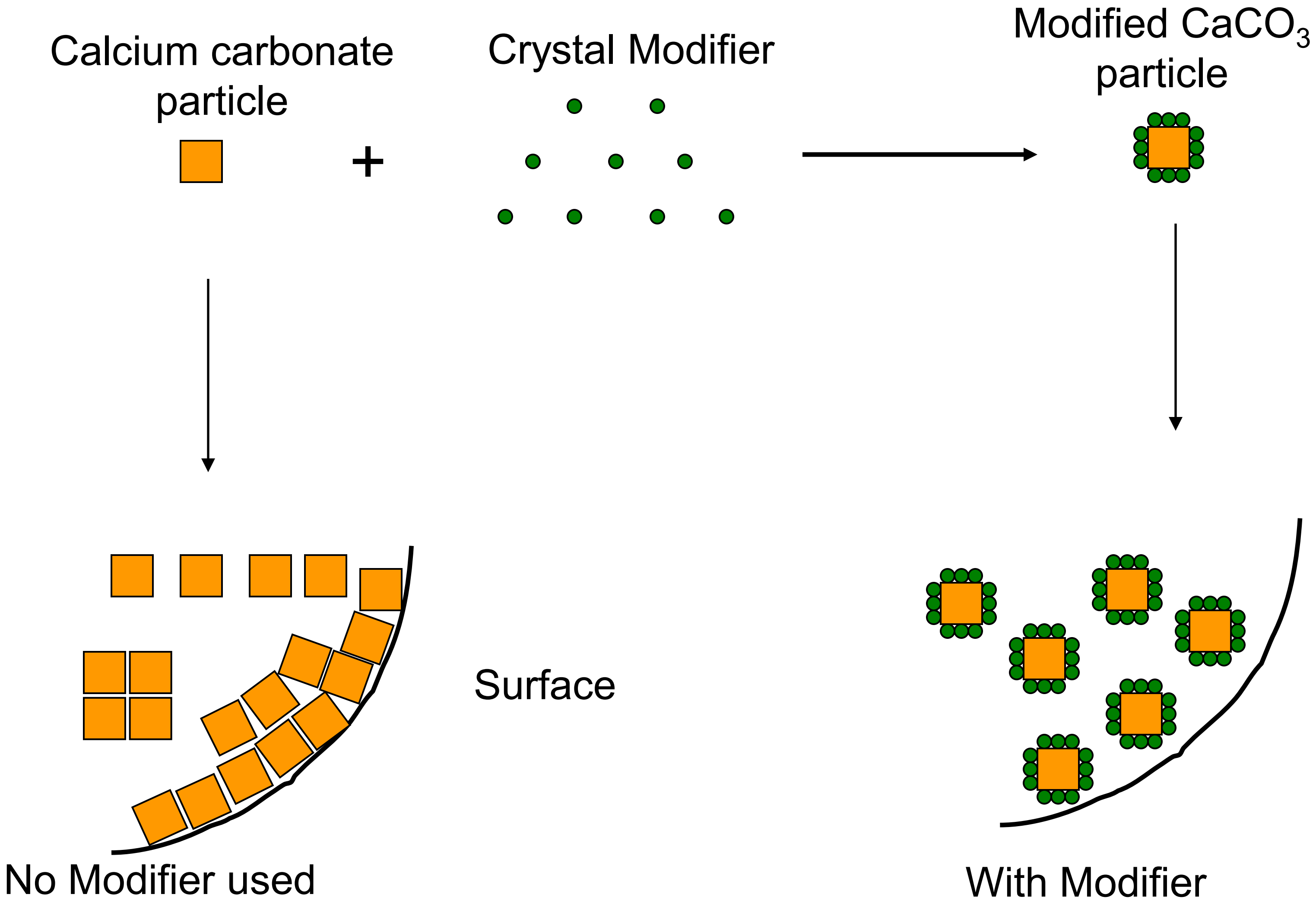
(Polymaleic acids and sulphonated polystyrenes)

Scale inhibitors are controlled by

- Sequestration
- Threshold Inhibition
- Crystal Modification

Scale Inhibitors	Threshold	Crystal Modifier
Polyphosphates	yes	
Phosphonates	yes	
Phosphate Esters	yes	
Poly carboxylic acids	yes	yes
Polymaleic acid		yes
sulphonates		yes

Crystal Modifier



Calcium carbonate particle

+

Crystal Modifier

Modified $CaCO_3$ particle

Surface

No Modifier used

With Modifier

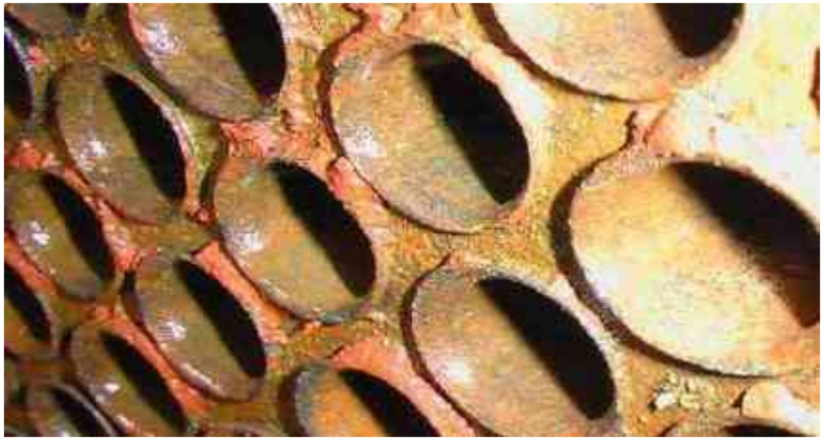
Scale Inhibitor dosage

If PSI or RSI is	ppm of active Phosphonate (HEDP)	ppm of Polyacrylate (1000 mol. Wt.)
6.0 or above	-0-	-0-
6.0 to 5.5	0.2 to 0.5	0.5 to 1.0
5.5 to 5.0	0.5 to 1.2	1.0 to 3.0
5.0 to 4.5	1.2 to 2.2	3.0 to 5.0
4.5 to 4.0	2.2 to 3.2	Can’t be controlled with Polyacrylate
Below 4.0	Can’t be controlled with phosphonate	

Corrosion

Corrosion is an electrochemical process by which a metal such as mild steel returns to its natural state.

Deterioration and perforation of heat exchanger tubes can result in lost product, system contamination and inefficient operation. Such damage requires downtime for maintenance, equipment replacement etc all leading to increased production costs.



CORROSION

Anode

$Fe \rightarrow Fe^{2+} + 2e^-$

$Fe^{2+} + 2OH^- \rightarrow Fe\,(OH)_2$

$Fe\,(OH)_2 + H_2O + 1/2\ O_2 \rightarrow Fe\,(OH)_3$

$Fe\,(OH)_3 \rightarrow Fe_2O_3\,.\,H_2O + 2H_2O$

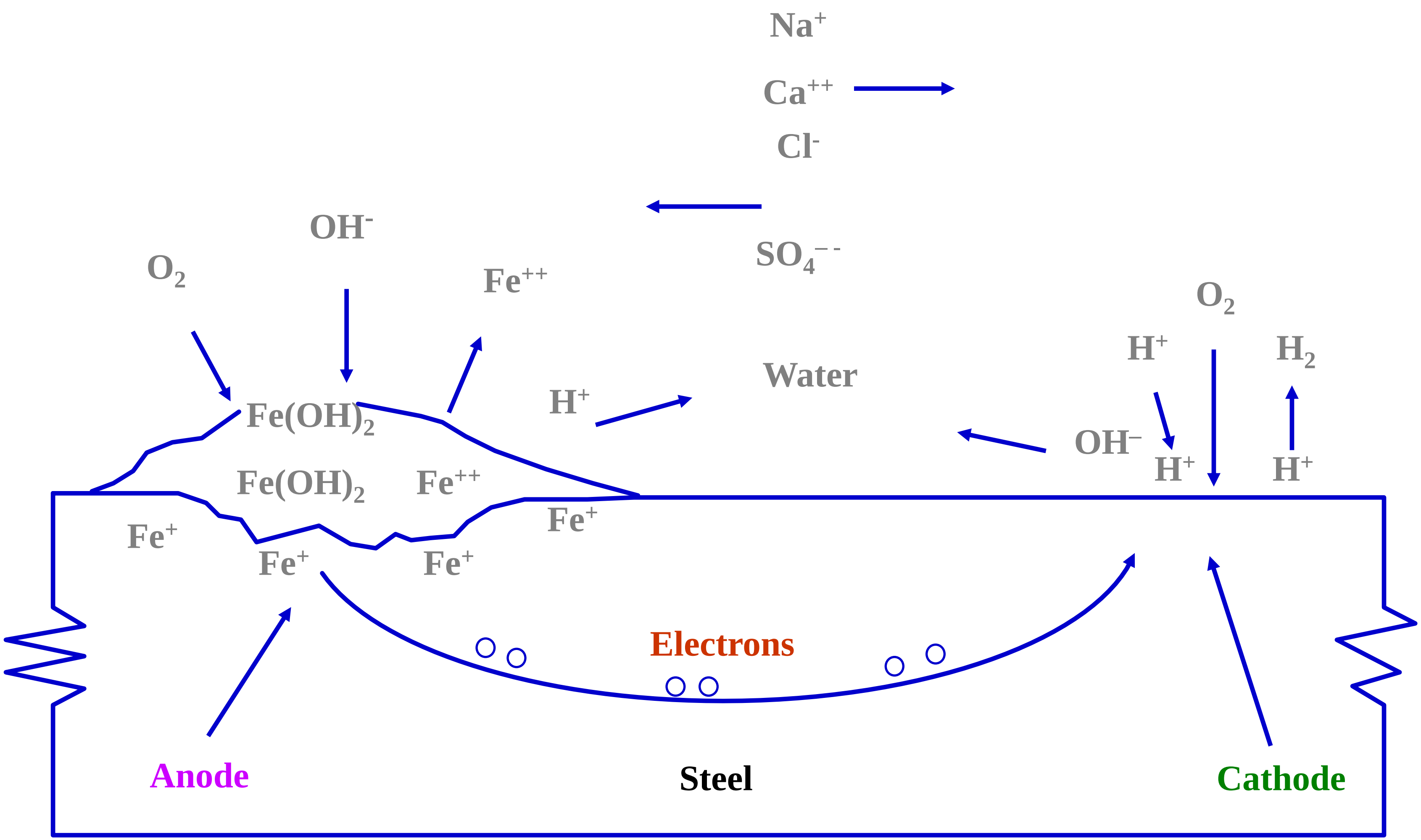
Cathode

$2\ H^+ + 2e^- \rightarrow H_2$

$4H^+ + O_2 + 4e^- \rightarrow 4\ OH^-$

$O_2 + 2H_2O + 4e^- \rightarrow 4\ OH^-$

MECHANISM OF CORROSION



Na^+

Ca^{++}

Cl^-

SO_4^{--}

OH^-

O_2

Fe^{++}

H^+

Water

O_2

H^+

H_2

OH^-

H^+

H^+

$Fe(OH)_2$

$Fe(OH)_2$

Fe^{++}

Fe^+

Fe^+

Fe^+

Fe^+

Electrons

Anode

Steel

Cathode

Corrosion Cell

TYPES OF CORROSION

Corrosion falls into three basic categories

1. GENERAL CORROSION
2. LOCALISED PITTING CORROSION
3. GALVANIC CORROSION

General corrosion takes place over the entire metal surface while localised pitting takes place at a small anode and because of smaller area is typically more severe.

Galvanic corrosion occurs when one metal sacrifices itself to protect another. This would occur when two dissimilar metals are in contact.

Scaled/Fouled Condenser tube

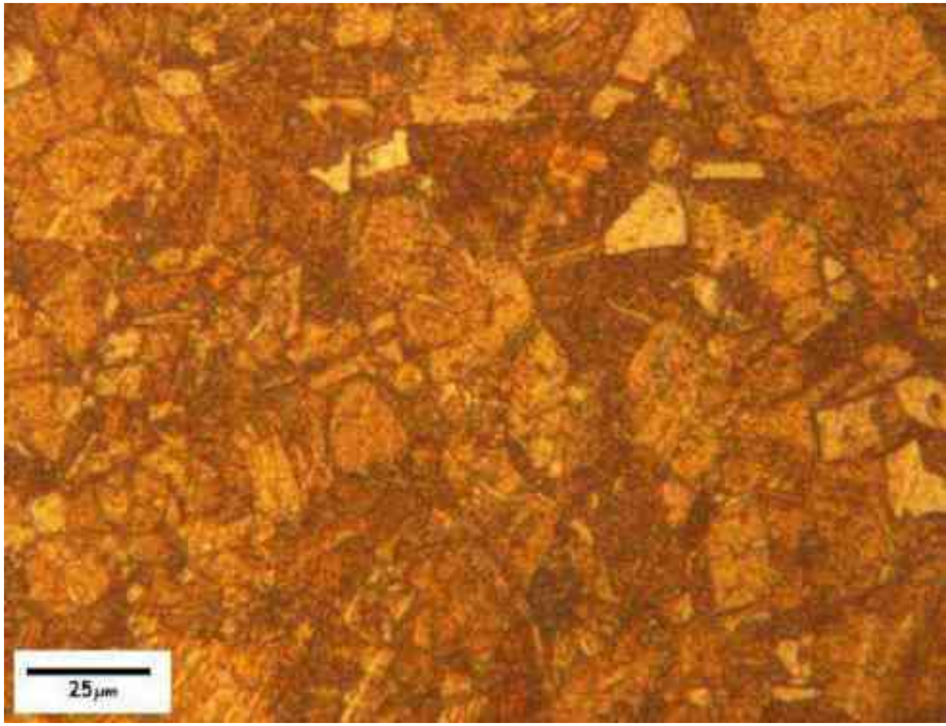
Greenish porous deposits on the condenser Tube

Condenser Tube after cleaning

Internal surface of condenser tube after cleaning showing dezincification and pitting

Microstructure of condenser tube

Typical microstructure of the tube surface showing severe attack



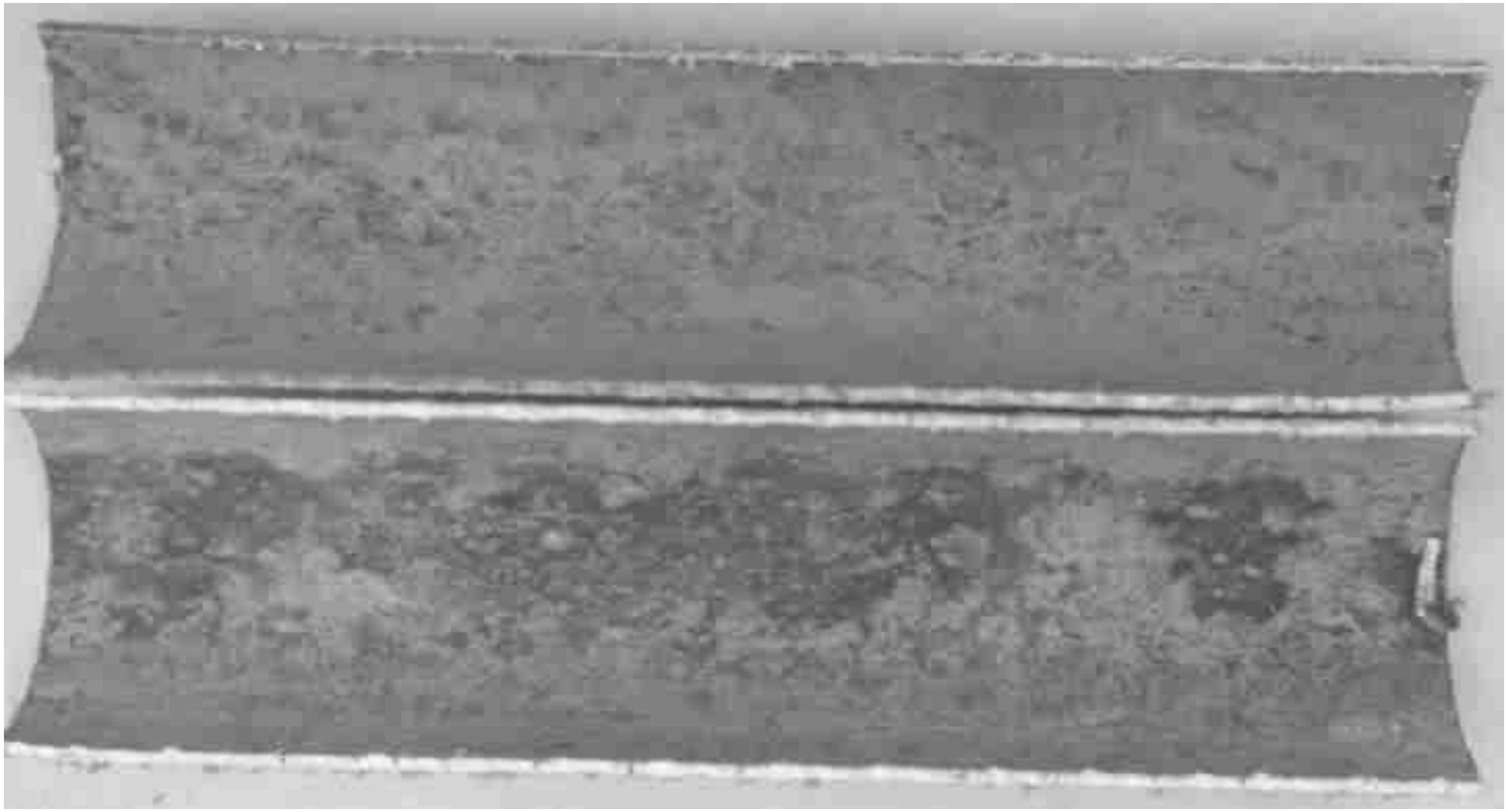
Microstructure of condenser tube showing pits and Inter-granular attack

Corrosion in condenser tube at tube plate site

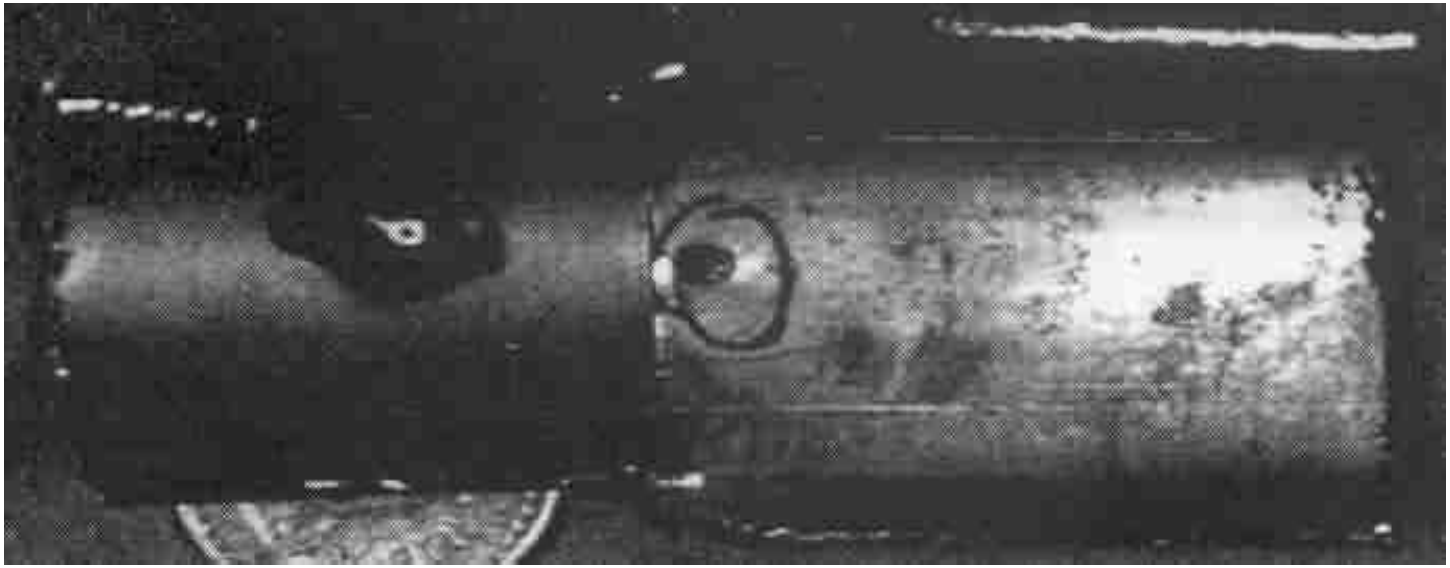
STEAM IMPINGEMENT/AMMONIA ATTACK OF ADM. BRASS CONDENSER TUBE

Cases of corrosion in condenser tube

Cases of corrosion in condenser tube

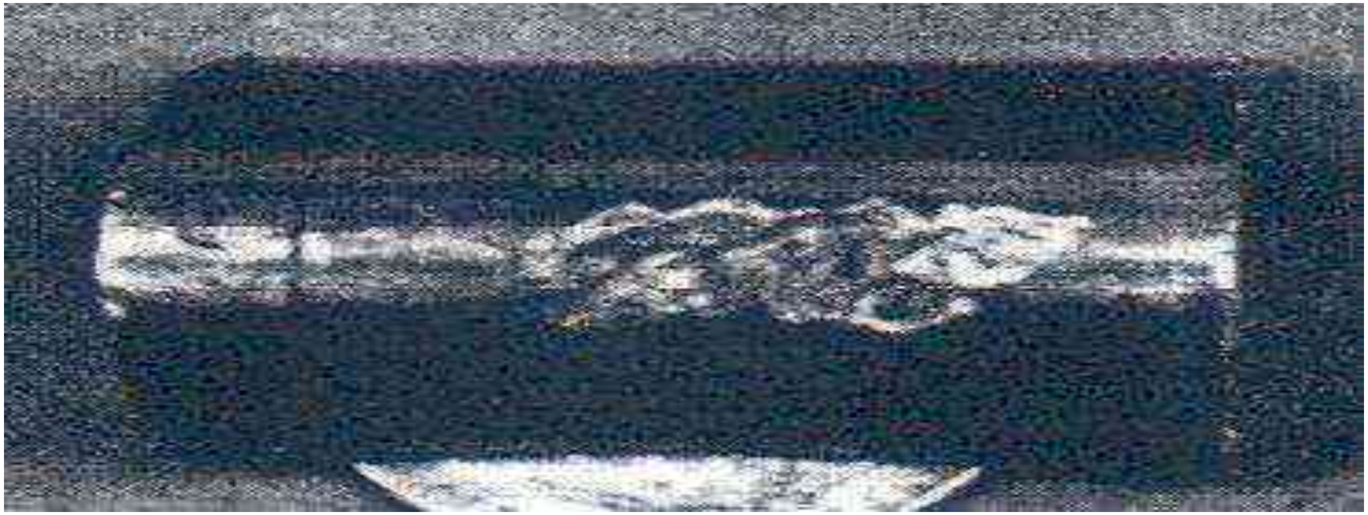


Cases of corrosion in condenser tube



CREVICE & PITTING CORROSION OF SS CONDENSER TUBE

Cases of corrosion in condenser tube



CREVICE & PITTING CORROSION OF SS CONDENSER TUBE

CORROSION IN CW SYSTEM

- PIPELINES
- CONDENSER WATER BOXES
- TUBE PLATES
- CONDENSER TUBES
- INLET END OF CONDENSER TUBES
- PUMPS
- BOILER TUBES (CARRY OVER)
- AUXILLIARY COOLING WATER SYSTEM
- HEAT EXCHANGERS

Causes of Corrosion

- Dissolved Oxygen
- Dissolved and suspended solids
- Acidity – Alkalinity
- Water velocity
- Temperature
- Microbiological Growth
- High Chloride /sulphate
- Fouling/ Under deposit corrosion

The pH or alkalinity of the water is extremely important as it affects corrosion significantly.

As a general rule, corrosion potential decreases when pH increases, but as the pH increase so does the potential for scale.

CORROSION CONTROL

- pH adjustment
- Polyphosphate dosing, SHMP
- Ferrous sulphate dosing
- Cathodic Protection
- Corrosion inhibitors
- Corrosion resistant materials in Condenser i.e Titanium
- Anti corrosive coating
- Keeping the system clean

Corrosion Inhibitors

Corrosion inhibitors are used to control the corrosion in CW system, which are

Phosphates -When added to the system in presence of calcium hardness will form a cathodic inhibitor.

- Chromates : Anodic inhibitor
- Zinc : Cathodic inhibitor, which provides excellent pitting corrosion protection.
- Tiazoles : An anodic inhibitor that specifically protects system copper based metals.
- Phosphonates : Cathodic inhibitor which will form monomolecular film on metal surfaces.
- Molybdates : A non toxic heavy metal that is excellent anodic inhibitor

CORROSION INHIBITORS

ANODIC	CATHODIC
Chromate	Polyphosphate
Orthophosphate	Zinc
Nitrite	Molybdate
Orthosilicate	Phosphonates

Corrosion Monitoring

System corrosion rates can be measured with the use of:

- Corrosion Coupons
- Corrosion Rate Monitor (Corrater)
- Water chemistry parameters (Water balance)

Corrosion Rate calculation by weight loss

$$\text{C.R. (mpy)} = \frac{22.3 \times W}{D \times A \times T}$$

MPY = Mils Per Year

W = Weight Loss (mg)

D = Specific Gravity (gm/cm^2)

A = Exposed Area (inch^2)

T = Time (Days)

1 MM = 40 Mils

1 MIL = 25 Microns

FOULING

- Fouling is deposition of suspended solids or buildup of microbiological organisms within heat exchanger and cooling tower fills.
- Warm water, aeration nutrients and sunlight transform a cooling tower into an efficient bio-reactor.

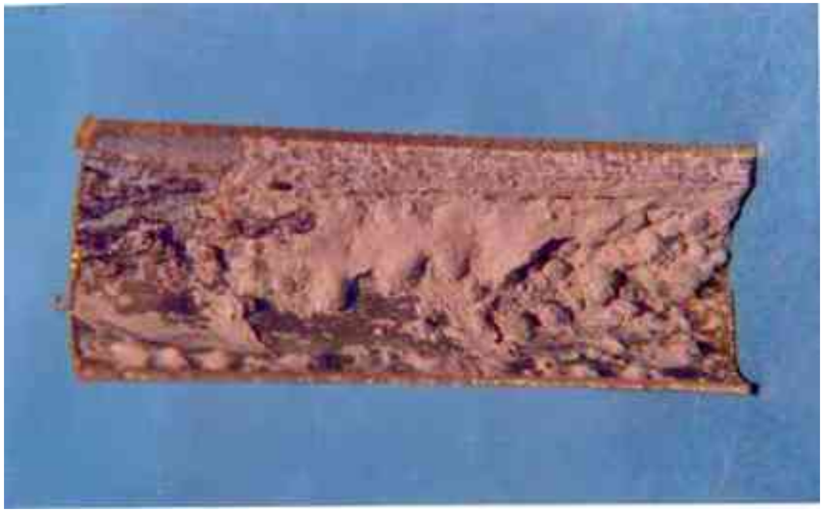
Types of fouling

- General Fouling by silt
- Fouling by corrosion products
- Microbiological Fouling

CT FILL FOULING

SEVERE BIOFOULING OF COOLING TOWER

FOULING BY CORROSION PRODUCT



BIOFOULING OF ADM. BRASS

THE BIOFOULING PROCESS

Bacteria prefer to colonise surfaces

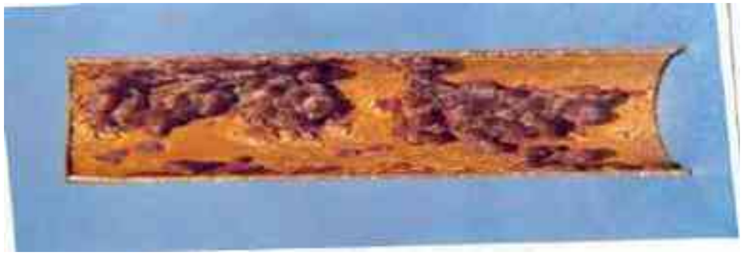
- enables production of biofilm which acts to protect and entrap food sources

- Planktonic bacteria
  - free swimming in bulk water
- Sessile bacteria
  - attached to surfaces

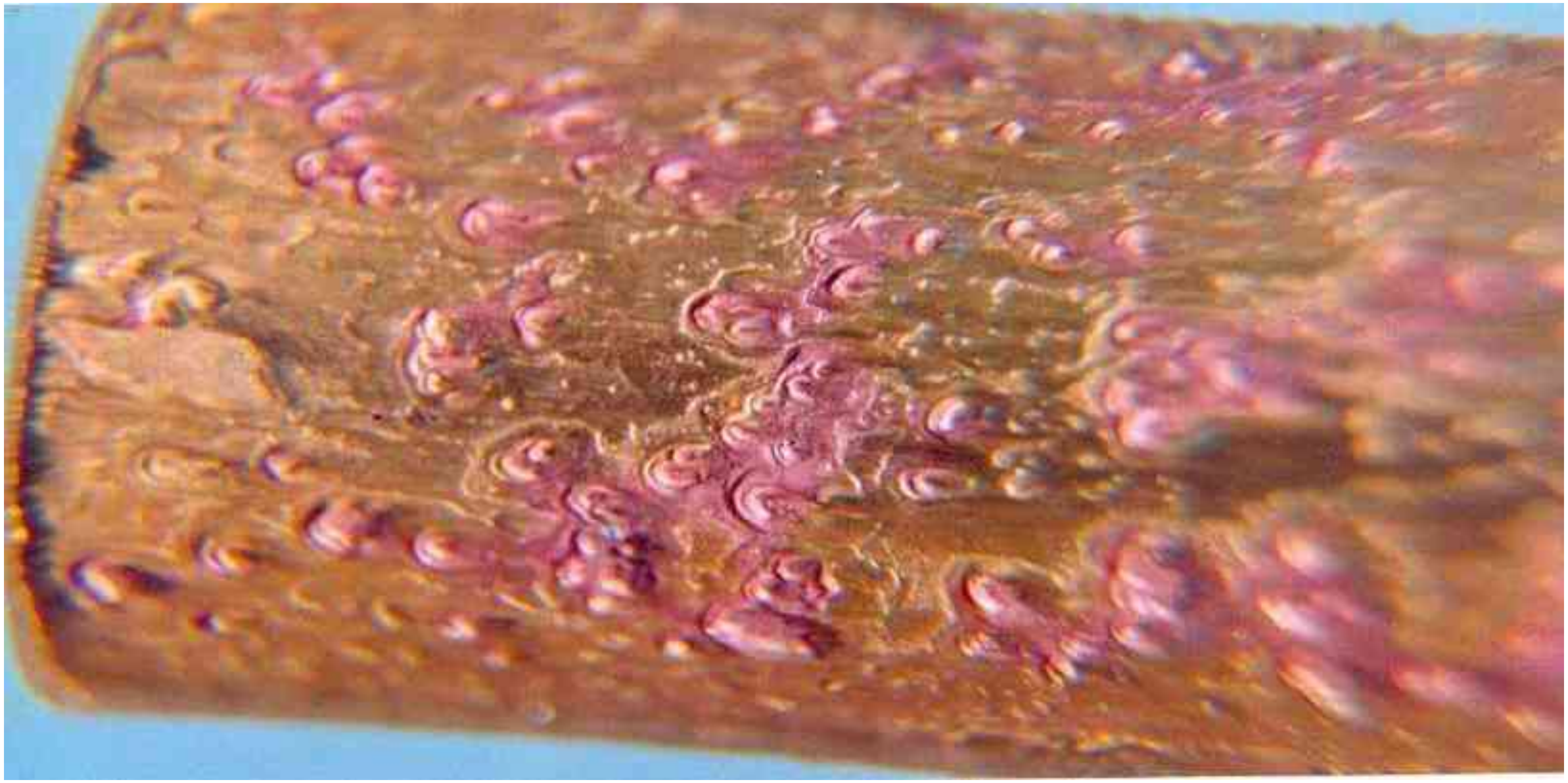
Biological Deposition and Corrosion

Fouling - Biological problems are created by both large and microscopic organisms. These are weeds, floating debris, mussels, oysters etc.

MIC- Microbiological problems are generally referred to as slime deposits such as algae, fungi and bacteria. The gelatinous slimes produced by many micro organisms can trap sediments thus encouraging fouling and scale. Even corrosion can be caused by certain organisms that produce corrosive byproducts or environments. Corrosion by micro organism is called Microbiological Induced corrosion (MIC).

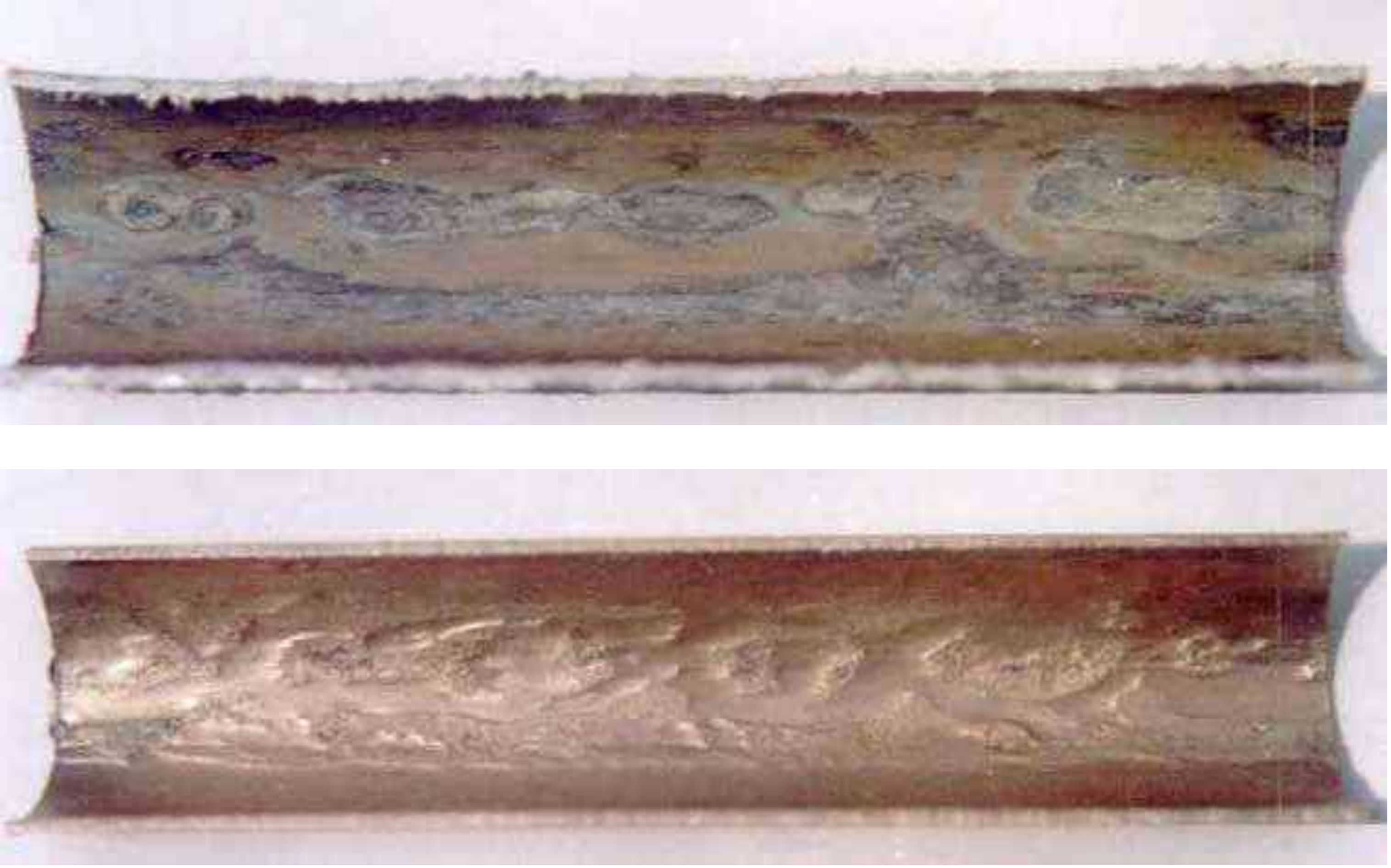


Micro biological corrosion in condenser tube



MIC OF ADM. BRASS IN CONDENSER TUBES SHOWING HORSE SHOE SHAPE

Corrosion in condenser tube



MIC OF CONDENSER TUBE BEFORE AND AFTER CLEANING

BIOFILM FORMATION

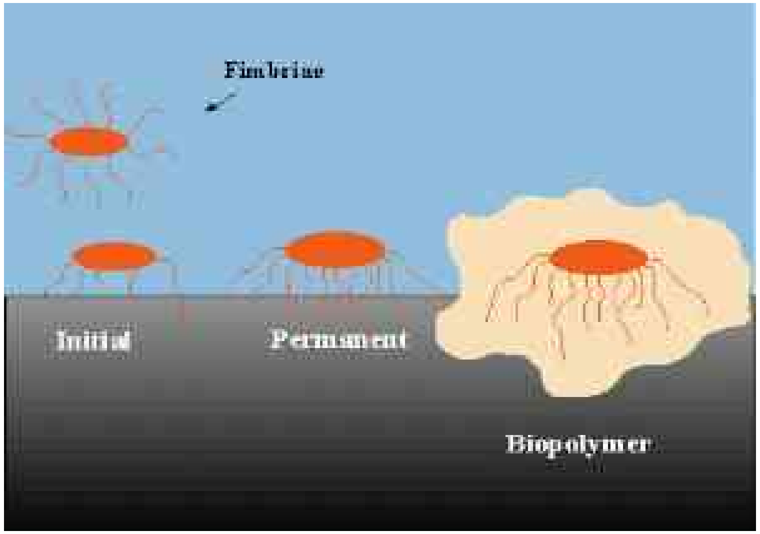
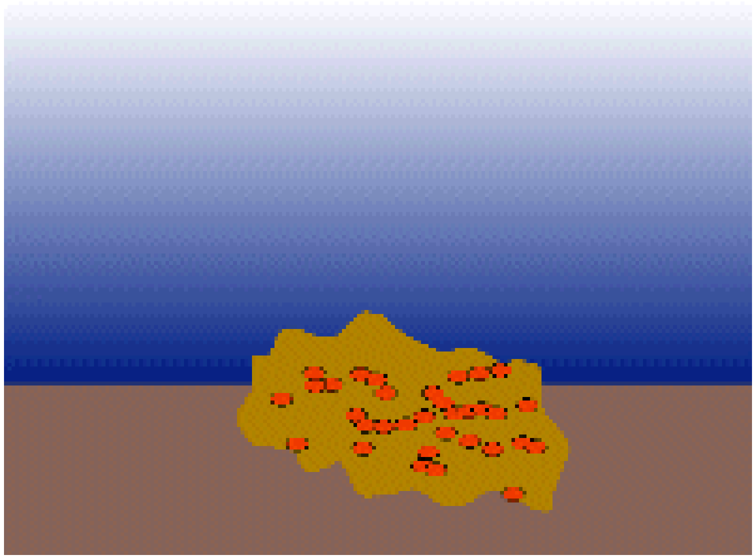
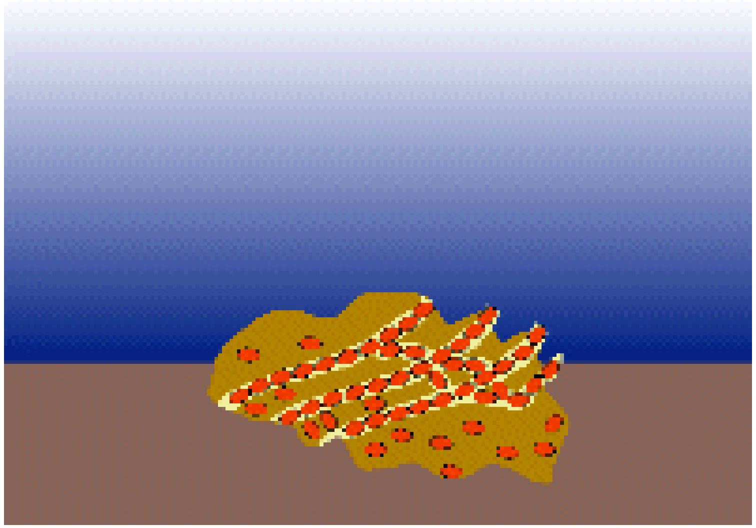


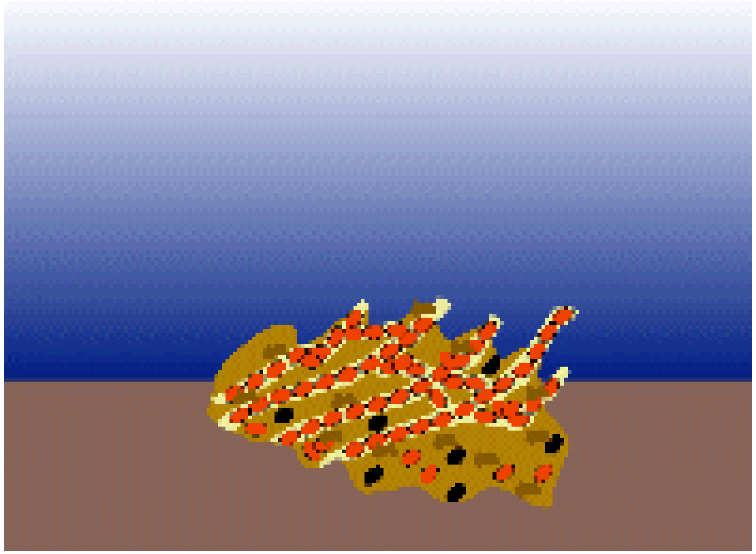
Fig.1 - Attachment of bacteria to surfaces



Initial Development



Maturation



Accumulation of debris

EFFECTS OF FOULING / BIOFOULING

Problems associated with biofilms

- Fouling of Cooling Tower, distribution pipeline, heat exchangers
- Reduction in heat transfer efficiency
- Lost production
- Under deposit corrosion
- Inactivation/ interference with inhibitors

Thermal conductivity comparison of deposit-forming compounds and biofilm

Substance	Thermal Conductivity ($W\ m^{-1}K^{-1}$)
$CaCO_3$	2.6
$CaSO_4$	2.3
$Ca_3(PO_4)_2$	2.6
Fe_2O_3	2.9
Analcite	1.3
Biofilm	0.6

Bio - Fouling Control

Biocides are used to control microbiological fouling and organic fouling in cooling water. Continuous chlorine dosing is done for better bio-fouling control.

Types of Biocides

- Oxidising Biocides
  - **Have the ability to oxidise organic matter eg. protein groups**
- Non-oxidising Biocides

  Prevent normal cell metabolism in any of the following ways :
  - **Alter permeability of cell wall**
  - **Destroy protein groups**
  - **Precipitate protein**
  - **Block metabolic enzyme reactions**
- Biodispersants (nonionic surfactants) are used to enhance the effectiveness of biocides

Oxidising Biocides

Various Oxidizing Biocides used in cooling water system are as follows:-

A. Chlorine and its various products

B. Chlorine oxide

C. Ozone

D. Hydrogen Peroxide

Oxidizing biocides are capable of undergoing oxidative reactions with organic molecules. They kill microorganisms on contact and dissipate to form harmless, non-toxic products. However, their activity is short and require frequent and continuous dosing. Also high dosages cause delignification of timbre and metallic corrosion.

Oxidising Biocides

- Rapid kill
- Cost effective
- Tolerant of contamination i.e. Chlorine Dioxide
- Minimal environmental impact i.e. Ozone, Hydrogen Peroxide, Chlorine Dioxide
- Ineffective against SRB’s
- Low residual toxicity
- Counts approaching potable water standards possible

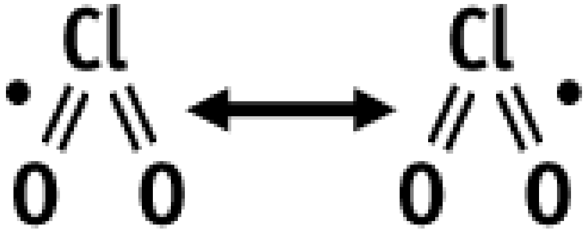
EFFECTIVENESS OF CHLORINE AS A BIOCIDE

EFFECT OF pH ON THE DISSOCIATION OF HYPOCHLOROUS ACID

pH	$HClO^-$
4	100
5	99.7
6	96.8
7	75.2
8	20.0
9	Negligible

EFFECTIVENESS OF CHLORINE DIOXIDE AS A BIOCIDE

Chlorine dioxide (ClO_2) is a synthetic yellowish-green gas with chlorine like odor. ClO_2 is unstable as a gas and will undergo decomposition into chlorine gas (Cl_2), oxygen gas (O_2) and heat. However, ClO_2 is stable and soluble in an aqueous solution. For example, solutions of approximately 1% ClO_2 (10 g/L) may safely be stored if the solution is protected from light and kept chilled. In solution, ClO_2 exists as a true gas. ClO_2 must be produced and used at the same location.



EFFECTIVENESS OF BIOCIDE

The biocidal efficiency, the stability, and the effects of pH on the efficiency of some disinfectants

Disinfectant	**Biocidal Efficiency**	**Stability**	**Effect of the pH Efficiency (pH = 6-9)**
Ozone	**1**	**4**	little influence
Chlorine Dioxide	**2**	**2**	efficiency slightly increases with the increase of pH
Chlorine	**3**	**3**	efficiency decreases considerably with the increase of pH

Non Oxidising Biocides

- Methylene bis-thiocyanate (MBT)
- Organo tin compound
- Quaternary ammonium salts
- Copper salts
- DBNPA (2,2-dibromo-3-nitrilopropionamide)

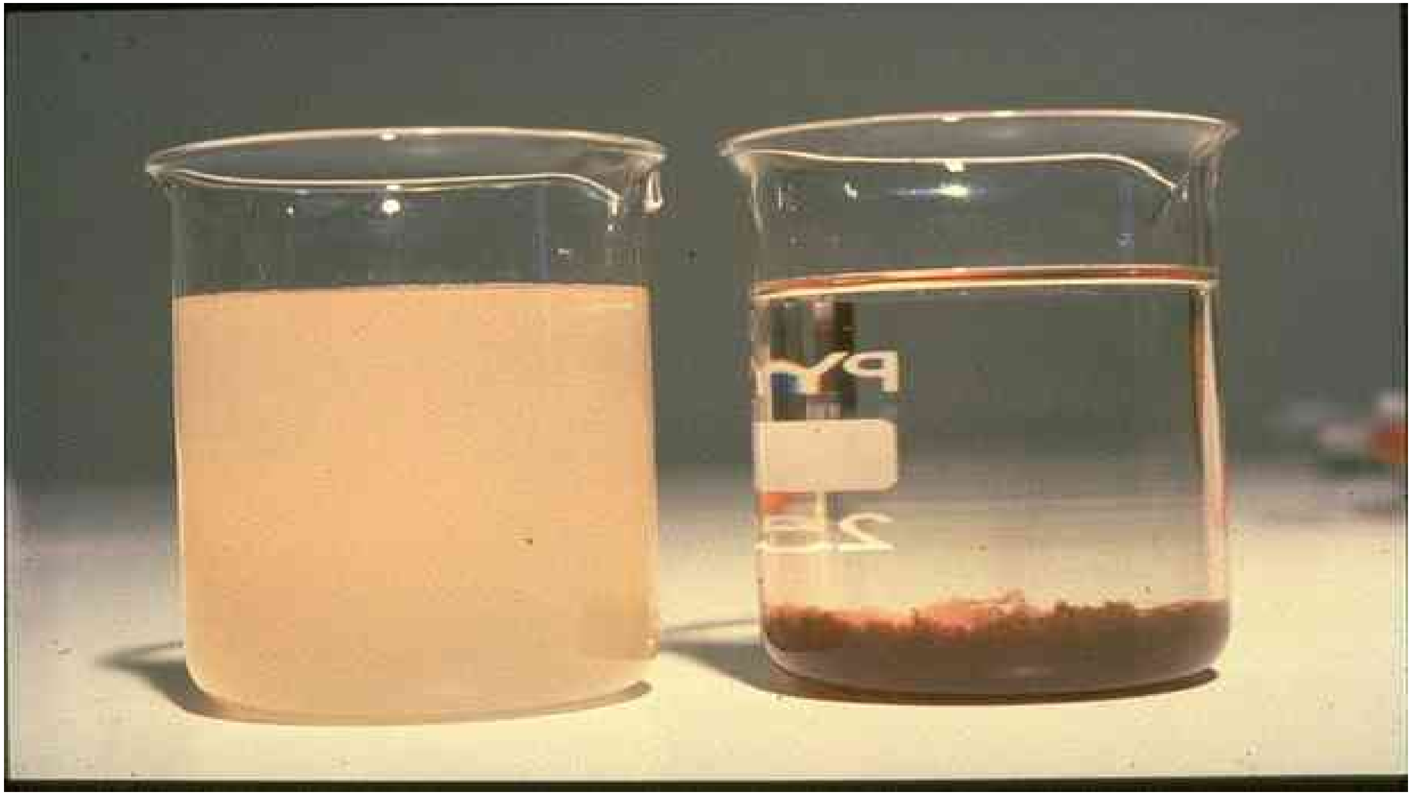
Non Oxidising Biocides

- Select alternating biocide to prevent resistant strains from developing
- Effective against SRB’s
- Can protect system long after dosing.
- Contain bio dispersant
- Higher dosage for kill possible

BIODISPERSANTS

- Improves penetration of biocide within bacterial slime
- Disperse released bacteria and biofilm into bulk water for removal by blow down
- Reduces ability for bacteria to attach to system surface
- Improves performance of both non oxidising and particularly oxidising biocides

SUSPENDED MATTER



- DUST/DIRT
- CONTAMINANTS e.g. OIL
- BIOLOGICAL e.g. ALGAE, FUNGI, BACTERIA

CONTROL OF FOULING IN CT FILLS

Mechanical Methods –

- Filters for Make up water – To remove suspended matter from Make up water

- Side Stream Filters – To remove suspended matter from CT basin

- CT Air Filters – To prevent ingress of suspended matter/ bacteria from air

Note: Chemical treatment along with use of Filters will reduce treatment cost.

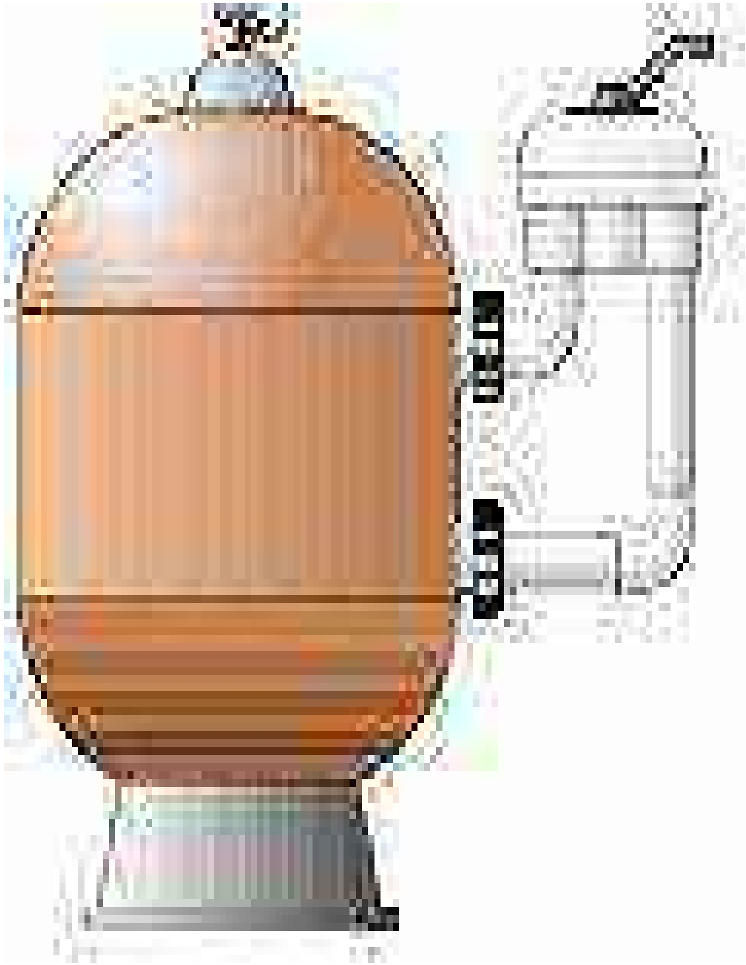
Control of Fouling in CW

- Filtration
- Cleaning – On–load / Off - load
- Blow Down

Control By chemicals

1. Dispersants
2. Sludge fluidizers – High molecular weight polymers
3. Surfactants
4. Biocides

CONTROL OF FOULING IN CT FILLS



Side steam Filter

Benefit of a Filter in an Open CW system

Keep the system clean

Reduce Biocide requirement

Prolong the life of mechanical equipments

Provides a warning of sudden system disruption

Reduce downtime

Reduce maintenance and energy cost

Reduce erosion of pump parts and equipment's

Maintain heat transfer efficiency

CONTROL OF FOULING IN CT FILLS

AIR INTAKE FILTERS FOR COOLING TOWERS

FOULING INHIBITOR

MONO-POLYMERS,

CO-POLYMERS,

TER-POLYMERS,

HOMO-POLYMERS OF POLYACRYLIC ACID,

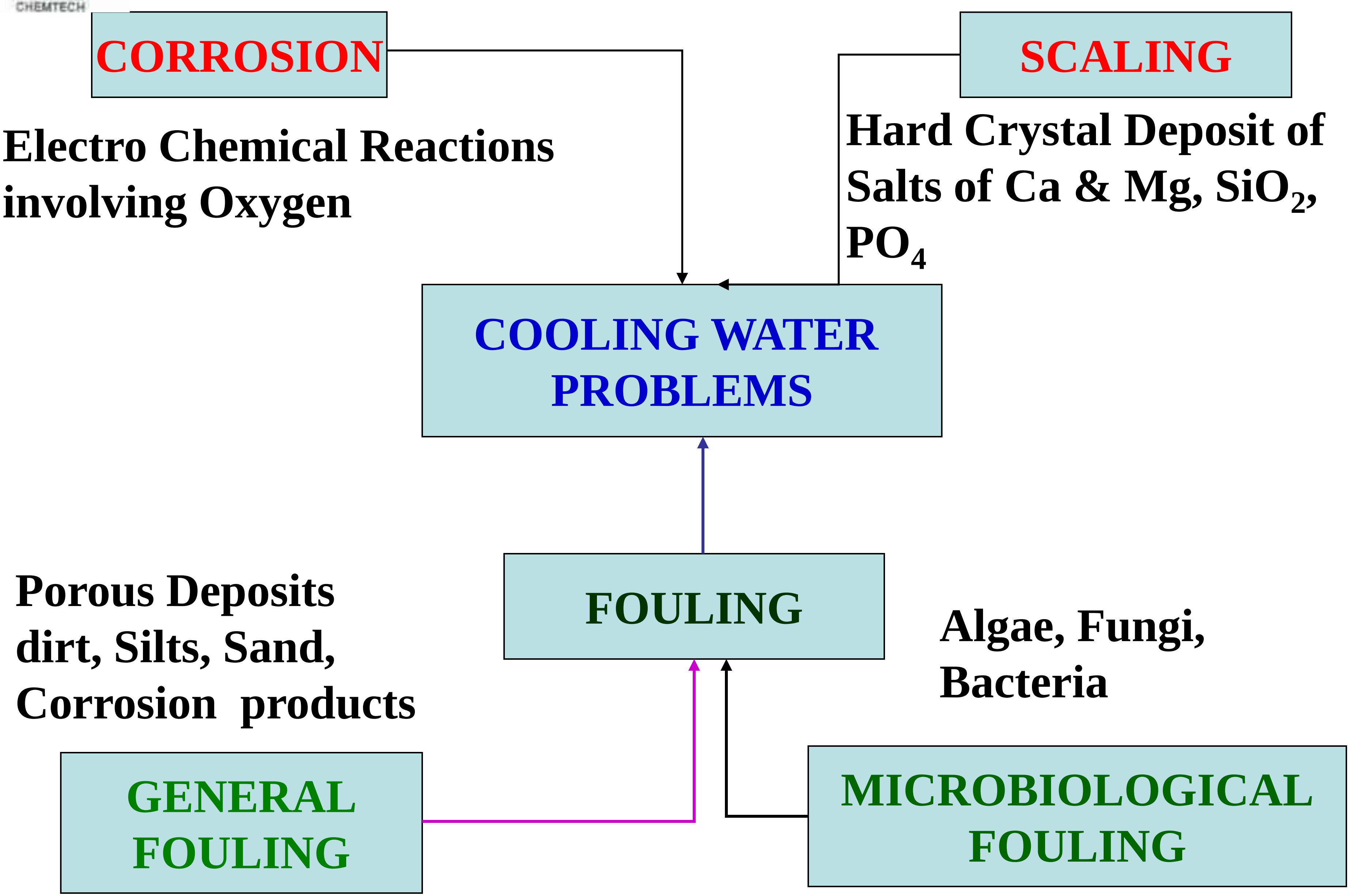
POLYMAELIC ACID,

POLYSULPHONIC ACID,

PBTC,

HEDP

THEY ARE USED IN DIFFERENT COMBINATIONS AND/OR BLENDED WITH OTHER ANTISCALANT, CORROSION INHIBITORS, DISPERSANTS, ETC



CORROSION

Electro Chemical Reactions involving Oxygen

SCALING

Hard Crystal Deposit of Salts of Ca & Mg, SiO_2, PO_4

COOLING WATER PROBLEMS

FOULING

Porous Deposits dirt, Silts, Sand, Corrosion products

Algae, Fungi, Bacteria

GENERAL FOULING

MICROBIOLOGICAL FOULING

Integrated Cooling water treatment

Key elements of cooling water treatment

1. Scale control- Ca, Mg Compounds & silicates
   - Use of threshold inhibitors- phosphonate or/and polymeric compounds
2. Corrosion Control
   - Use of cathodic, anodic & adsorption based inhibitors
3. Fouling Control – metal oxides, silt & suspended impurities
   - Use of Homopolymers & multifunctional Co-polymers & Ter-polymers
4. Microbiological control – Biofouling & microbiological induced corrosion
   - Use of oxidizing & non-oxidising biocides & bio-dispersants

Development of CW Treatment Program

1. Analysis of waters, deposits from the plants to assess the extent and nature of problem.
2. Analysis of data of water analysis (last one year) COC analysis with LSI, RSI & PSI calculations.
3. Assessment of actual site condition by visual inspection and process data (condenser in/out temp., condenser vacuum, flow rate, hot well temp, metallurgy etc.)
4. Development of methodology for removal of existing deposits on the CT fills, condenser tubes and other equipment's of CW system.
5. Development of chemical treatment program at laboratory based on lab studies. Selection of chemicals on the basis of above analysis.

Development of CW Treatment Program

6. Conducting Inhibitor Efficiency & Dispersing Capability tests and Corrosion Rate assessment for individual chemical in the laboratory as per applicable standards.
7. Preparation of formulations on the basis of residual conc. of each chemical to be maintained in CW system and lab results of individual chemical w.r.t scale inhibition efficiency, dispersing capability and corrosion inhibition. Repeating the tests in S.No-6 above for the formulations.
8. Validation of the laboratory data on a pilot scale.
9. Optimization of dosages and treatment program based on pilot scale studies. (**Simulation studies Dynamic Corrosion test Rig**)
10. Recommendations for assessing the effectiveness of the treatment program through appropriate monitoring techniques/equipment

Typical CW Treatment Formulation

Treatment may include

- Phosphate (Tri, hexa, ortho) TSP, SHMP
- Organo phosphonates: AMP, HEDP, PBTC
- Zinc Sulphate / molybdate
- Triazole: Benzo triazole (BTA), Toly Triazole (TTA)
- Dispersants mono, co or ter polymers of acrylates, sulphonates, maleic acid etc
- Bio-dispersant
- Biocides

Dosages & Residuals

The formulation is dosed in a manner so that the following residual concentrations of scale & corrosion inhibitors, dispersants, biocides is maintained in the system

Chemical	Residual
Inorganic phosphate as PO_4	2-3 ppm
Organic phosphate as PO_4	1.5-2.0 ppm
Zinc as Zn	0.5-1.0 ppm
Molybdate as MoO_4	0.5-1.0 ppm
Dispersant as polymer	1.0-2.0 ppm
Biocides Chlorine	0.2-0.5 ppm
ClO_2 (continuous)	0.05-0.1 ppm
Once daily	0.2 – 0.5 ppm

Calculation of Sulphuric acid dosing in CW System

The Treatment program is suitable for pH range from 7.5 - 8.3 and alkalinity upto 300 ppm. The upper limit of alkalinity is 300 ppm, beyond that sulphuric acid dosing would be required to maintain the alkalinity <= 300 ppm as per the following formula:

Sulphuric acid required (kg/day)

= {0.026 X (Circulating Water Alkalinity – 300) X Blow Down

(m3/hour)}

(Where 0.026 is a factor applied for calculations)

Attributes of Economy of Treatment program

- Knowledge of the system operating conditions
    - Metallurgy
    - Tolerance of impurities wrt COC
    - Effectiveness over Heat Transfer
    - Operating pH- Alkaline treatment may cost more but are flexible
- Calcite saturation : Higher LSI requires more antiscalants dose
- Treatment induced problems – eg High phosphate leads to more microbial growth
- Extent of monitoring – A better monitoring can reduce cost

Monitoring and Evaluation of Treatment Programme

- Monitoring

Continuous

1. pH
2. Water Level in sump
3. Blow Down Rate
4. Make up water rate
5. Temperature

Every shift

1. Residual Chlorine
2. Lengelier index
   Ryzner Index (RSI)

Monitoring and Evaluation of Treatment Program

- Complete Water Analysis

Make water and Circulating water (Daily)

1. pH
2. Alkalinity
3. Conductivity
4. Turbidity
5. Calcium and Magnesium Hardness
6. Chlorides
7. Silica
8. Iron
9. Treatment Chemicals

Evaluation of CW Treatment Program

- Corrosion Control

1. Corrosion Coupons
2. On-line corrosion/ Instant Corrosion meter

- Scale and Fouling control

1. Scale and fouling monitor
2. Heat transfer data
3. Periodic inspection

- Microbiological control

1. Regular microbiological analysis
2. On-line bio-fouling monitor
3. ORP monitor

ONLINE BIOFOULING MONITORING

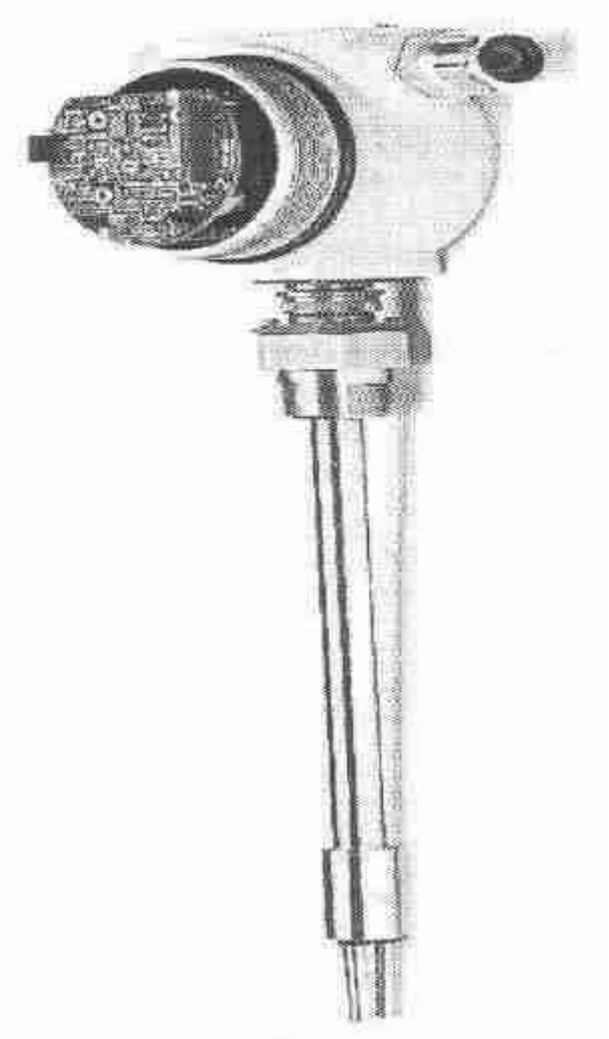
Figure 2 The BIoGEORGE™ probe.

ONLINE BIOFOULING MONITORING

FIGURE 4 - Probe Tapping on Cooling Water Return Line

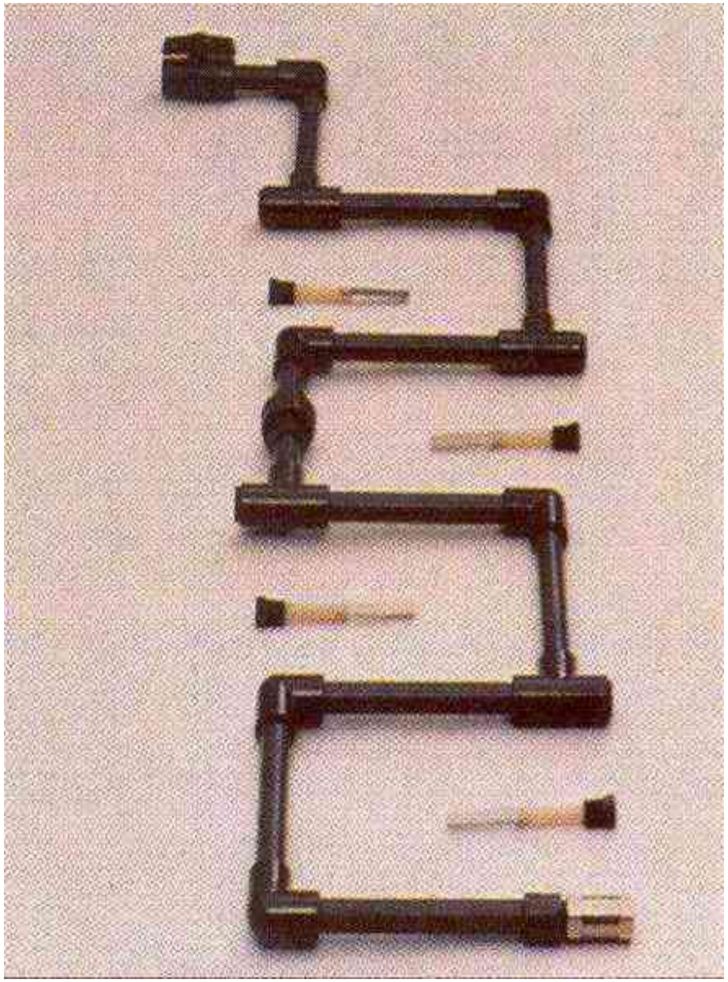
FIGURE 5 - View of Probe Installed in Tap

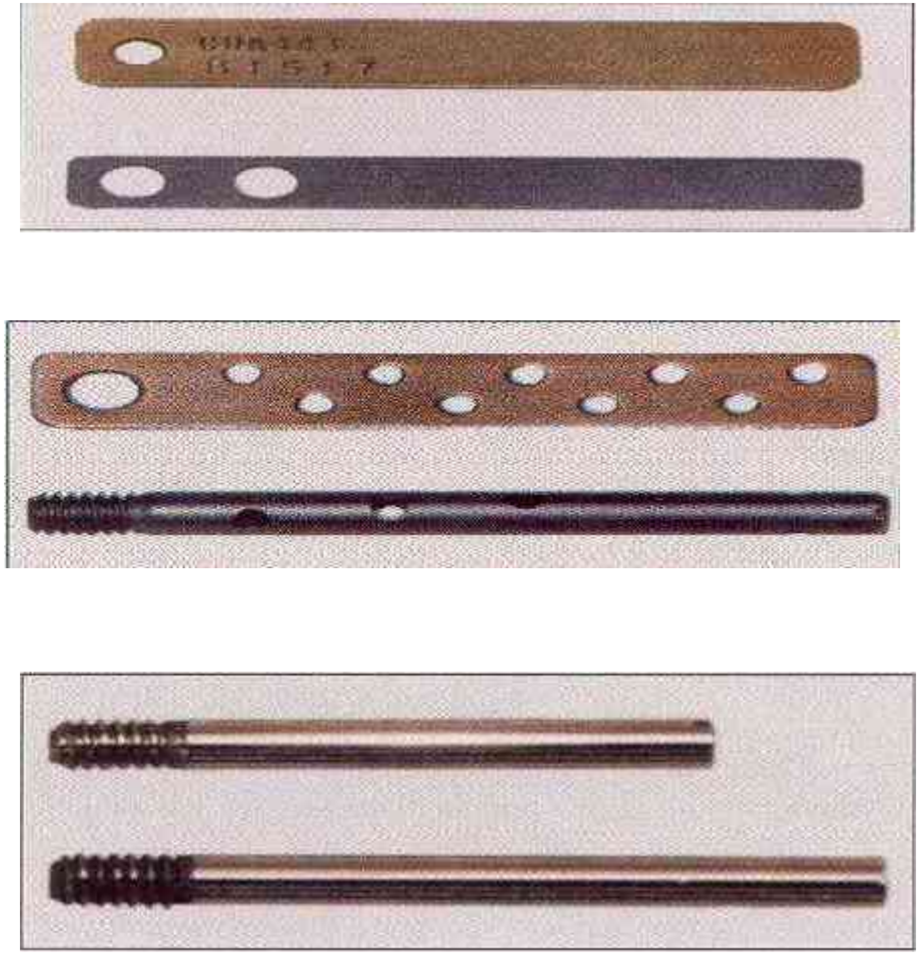
CORROSION RATE MONITORS FOR FIELD



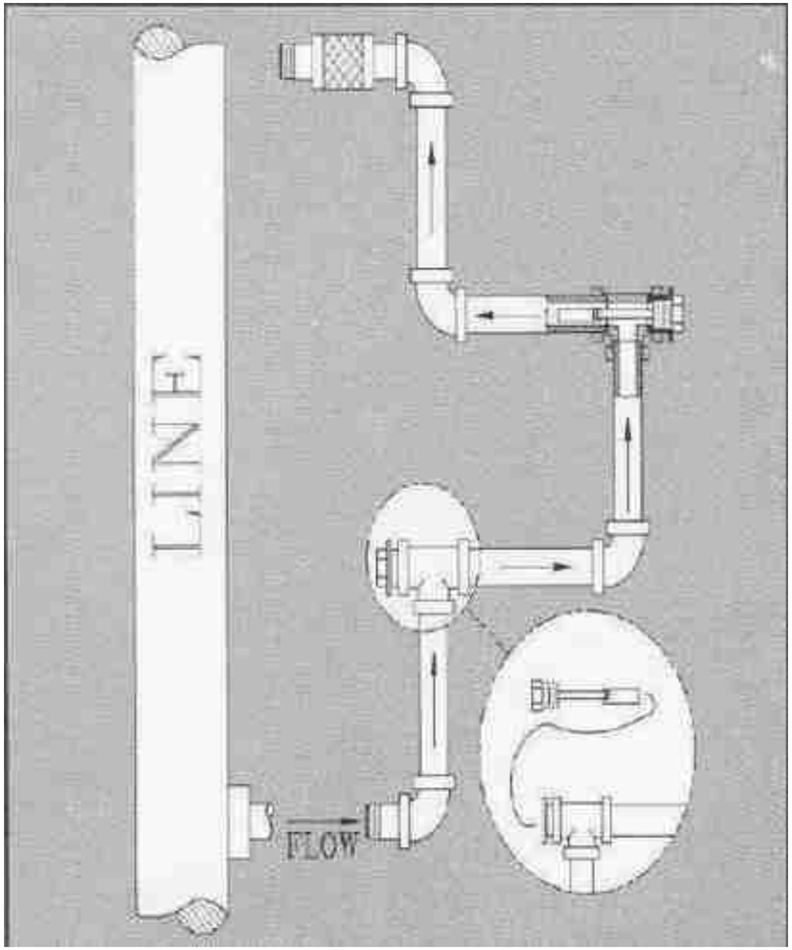
MS1000 CORROSION METER

CORROSION TEST RACK WITH TEST COUPONS FOR MONITORING OF CORROSION & SCALING IN CW SYSTEM





INPLANT CORROSION MONITORING OF CW SYSTEM THROUGH WEIGHT LOSS COUPONS



INPLANT BIOFOULING MONITORING OF CW SYSTEM

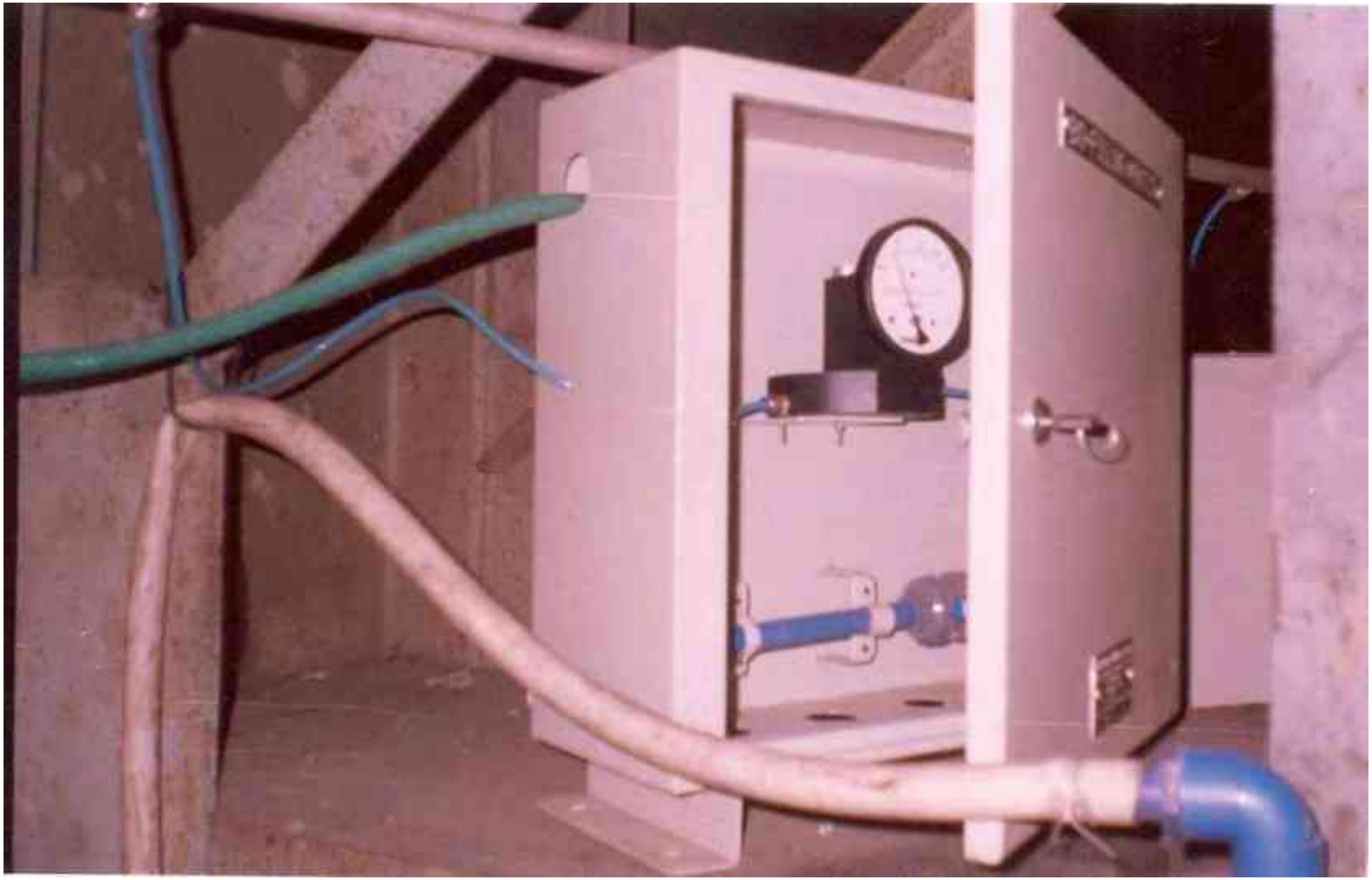


Table 2 – EPRI Guidelines for Cooling waters

Water Quality		EPRI Guidelines	Remarks
Parameter	Units		
Ca	mg/l CaCO3	900 (max)	
Ca X SO_4	$(mg/l)^2$	5,00,000	
M Alkalinity	mg/l CaCO3	30 – 50 220 - 250	Without Scale Inhibitor With Scale Inhibitor
Mg X SiO_2	mg/l CaCO3 X mg/l SiO2	35,000	
HCO_3+CO_3	mg/l CaCO3		
SO_4	mg/l		Refer to CaSO4 limit
SiO_2	mg/l	150	
PO_4	mg/l		
Fe (Total)	mg/l	< 0.5	
Mn	mg/l	< 0.5	

Table 2 – EPRI Guidelines for Cooling waters

Cu	mg/l	< 0.1	
Al	mg/l	< 1	
S	mg/l	5	
NH_3	mg/l	< 2	For copper based alloys present in the system
pH		6.0 – 7.2 7.8 – 8.4	Without Scale Inhibitor With Scale Inhibitor (Higher operating pH is possible with new alkaline treatments)
TDS	mg/l	70,000	
TSS	mg/l	< 50 < 100	For Film type Fill Splash type Fill
BOD	mg/l	<100	Consult with specialty chemical provider before finalising control parameters

Table 2 – EPRI Guidelines for Cooling waters

COD	mg/l	<100	----- do -----
LSI		< 0	
RSI		> 6	
PSI		> 6	

Guidelines for assessing Corrosion

Model	Corrosion rate (mpy)	Comments
Carbon Steel	0-2	Excellent corrosion resistance
	2-3	Generally acceptable for all systems
	3-5	Fair Corrosion resistance acceptable with Iron fouling control program
	5-10	Unacceptable corrosion resistance
Admiralty Brass	0-0.2	Generally safe for heat exchanger tubing & Ms equipments
	0.2-0.5	High corrosion rate may enhance corrosion of mild steel
	>0.5	Unacceptable high rate for long term; significantly affects MS corrosion
Stainless steel	0-0.1	Acceptable
	> 0.1	Unacceptable corrosion resistance

Guidelines of assessing Biological count

Count Range	**Inference**
0 -10000	Essentially sterile
10000-500000	System under control
500000 - 1million	System may be under control but should be monitored
1 million – 10 million	System out of control- requires biocide
Over 10 million	Serious fouling problems may be occurring immediate biocide additive required

Use of Treated Sewage Water in Power Plant

Revised tariff policy GOI dt. 28.01.16

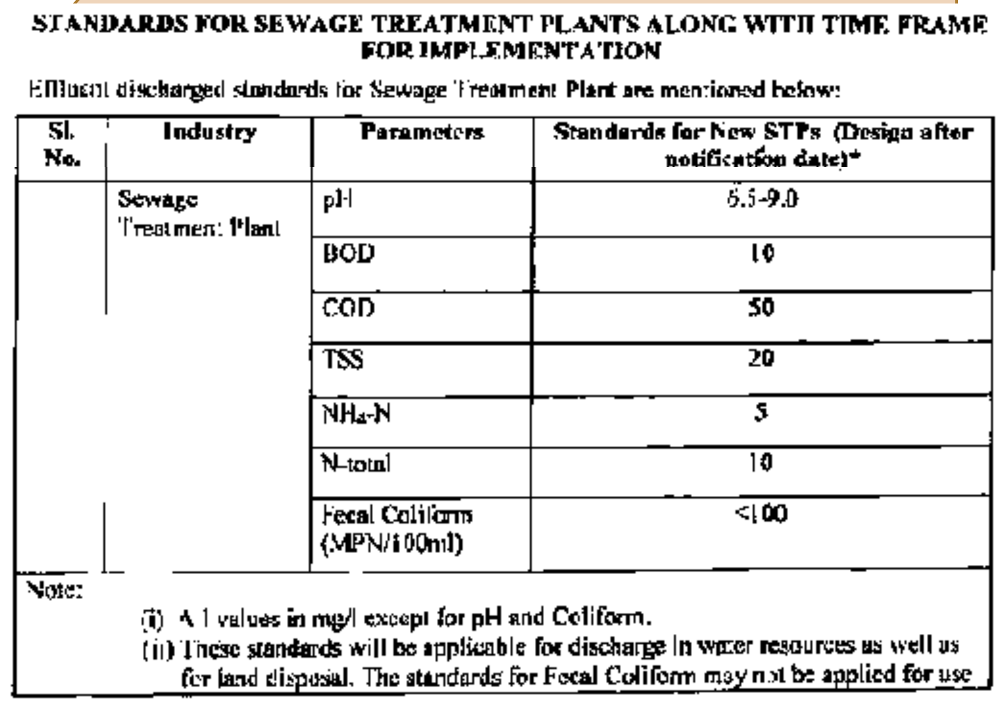
Thermal power plants incl. existing plants located **within 50 km radius** of STP of municipality/local bodies/ similar organization shall **mandatorily use treated sewage water** produced by these bodies

Such power plant will also ensure **backup source of water**

Associated cost to be allowed as a **pass through in the tariff.**

May require newer costlier technologies like reverse osmosis

Standard for new STP (MOEF & Climatic change draft notification Nov'15)



STANDARDS FOR SEWAGE TREATMENT PLANTS ALONG WITH TIME FRAME FOR IMPLEMENTATION

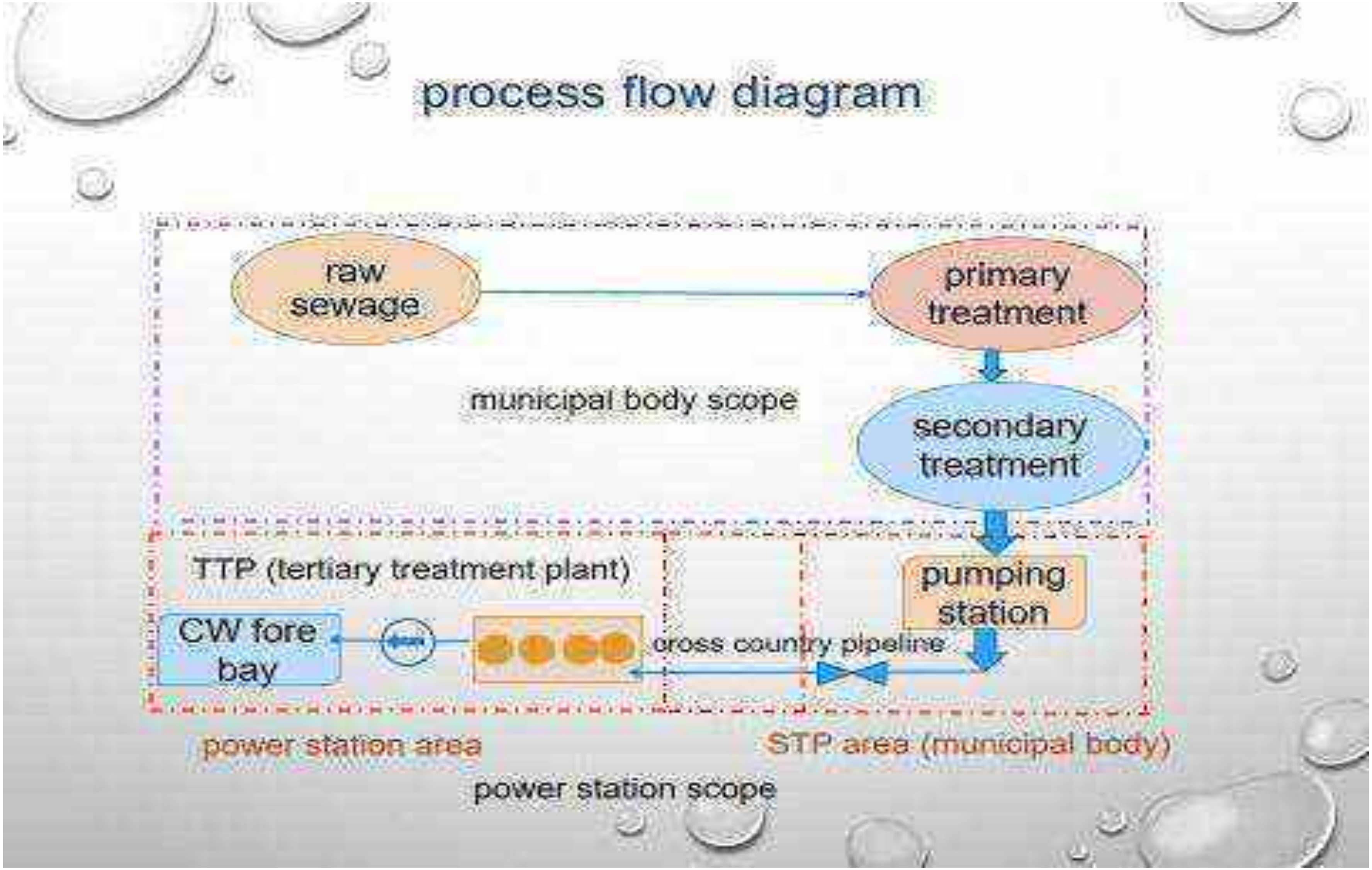
Effluent discharged standards for Sewage Treatment Plant are mentioned below:

Sl. No.	Industry	Parameters	Standards for New STPs (Design after notification date)*
	Sewage Treatment Plant	pH	6.5-9.0
		BOD	10
		COD	50
		TSS	20
		NH_3-N	5
		N-total	10
		Fecal Coliform (MPN/100ml)	<100

Note:

(i) All values in mg/l except for pH and Coliform.
(ii) These standards will be applicable for discharge in water resources as well as for land disposal. The standards for Fecal Coliform may not be applied for use

Use of Treated Sewage Water in Power Plant



process flow diagram

Use of Treated Sewage Water in NTPC Stations

Scanning of STPs done within 50 Km of NTPC plants all over India

Potential of using 560 MLD of treated sewage water identified based on the above assessment for following power stations

Projects	Capacity (MLD)
Solapur	90
Dadri	180
Meja	90
Patratu	48
Mouda	150

NTPC to utilise treated waste water from Noida, MoU ready

WATER CONSERVATION

PERIODIC CLEANING

MECHANICAL CLEANINGS

- ON - LINE CLEANING (COLTS)
- BULLETS CLEANINGS
- HIGH PRESSURE JETTING
- BACKWASHING

CHEMICAL CLEANING

- ACID – HYDROCHLORIC ACID, SULPHAMIC ACID
- CHELANTS
- PROPRIETARY CLEANING SOLVENTS

HYDROCHLORIC ACID (HCl)

$$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O$$

$$Fe_3O_4 + 8\ HCl = 2\ FeCl_3 + FeCl_2 + 4H_2O$$

- REACTS WITH MOST WATER FORMED SCALE AND CORROSION PRODUCTS TO FORM SOLUBLE CHLORIDES
- IN CASE OF BAD INHIBITION, IT CAN CAUSE CORROSION PHENOMENA OF LOCALISED PITTING TYPE
- TEMPERATURE MUST BE LIMITED TO 66°C
- LOWEST COST

SULPHAMIC ACID

$$HSO_3\text{- }OH + H\text{-}NH_2 \rightarrow HSO_3\text{-}NH_2$$

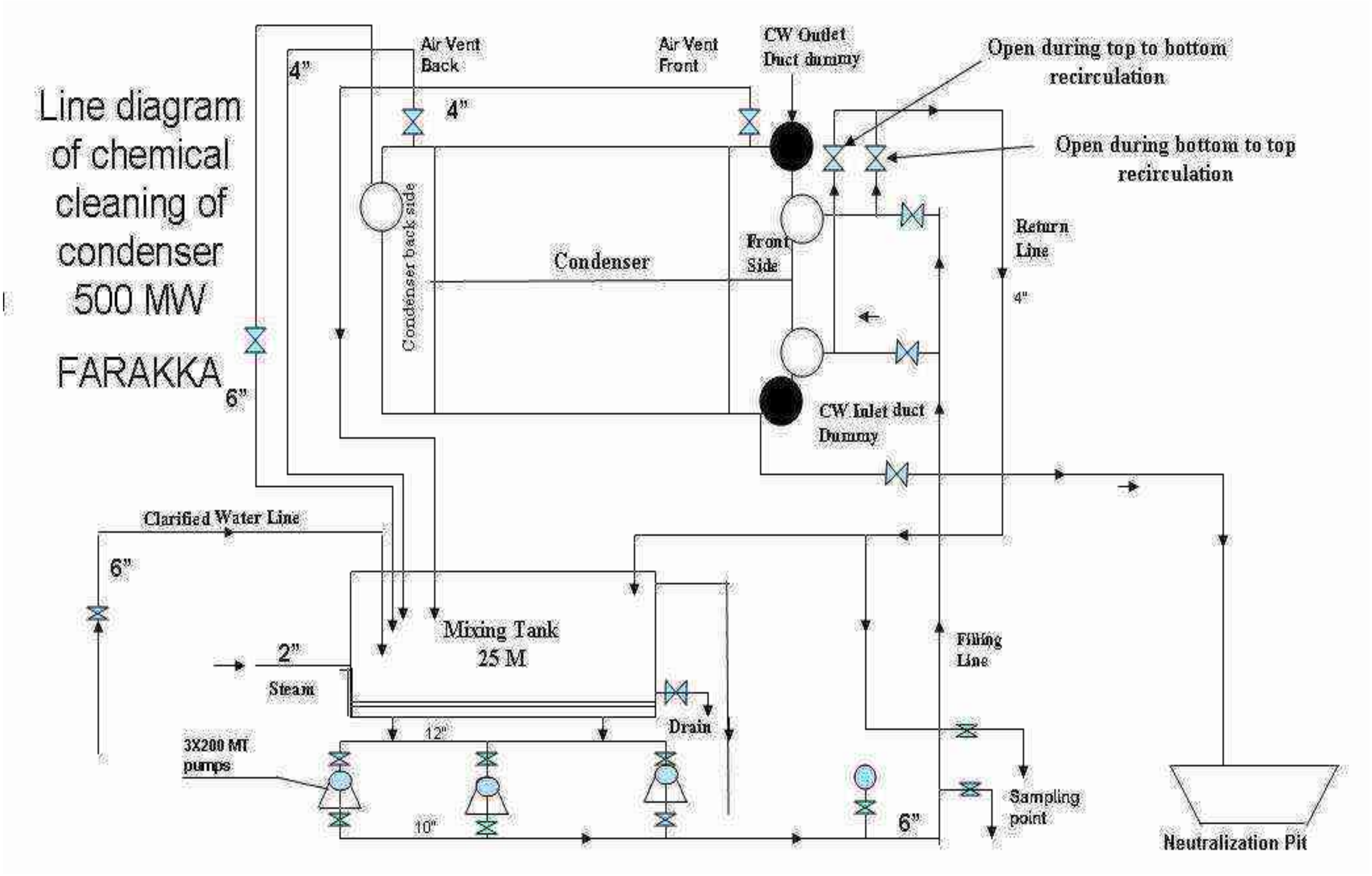
(Sulphamic acid)

$$2\ NH_2\text{-}SO_3H + Ca^{2+} \rightarrow (NH_2\text{-}SO_3)_2\ Ca$$

$$Fe_3O_4 + 8NH_2\text{-}HSO_3 \rightarrow 2Fe\ (NH_2SO_3)_6 + (NH_2SO_3)_2\ Fe + H_2$$

- SOLID CRYSTALS CONVERT IN ACID SOLUBLE WHEN DISSOLVED IN WATER
- IT’s CALCIUM SALTS ARE SOLUBLE IN WATER
- IT IS WEAKER THAN OTHER MINERAL ACIDS
- SULPHAMIC SALTS SLOWLY CHANGES TO SULPHATE WITH PRECIPITATION OF $CaSO_4$
- PRINCIPAL ADVANTAGE IS EASE OF HANDLING
- COST IS HIGH AS CPMPARED TO HCl

Schematic of Chemical cleaning circuit in 500 MW unit.

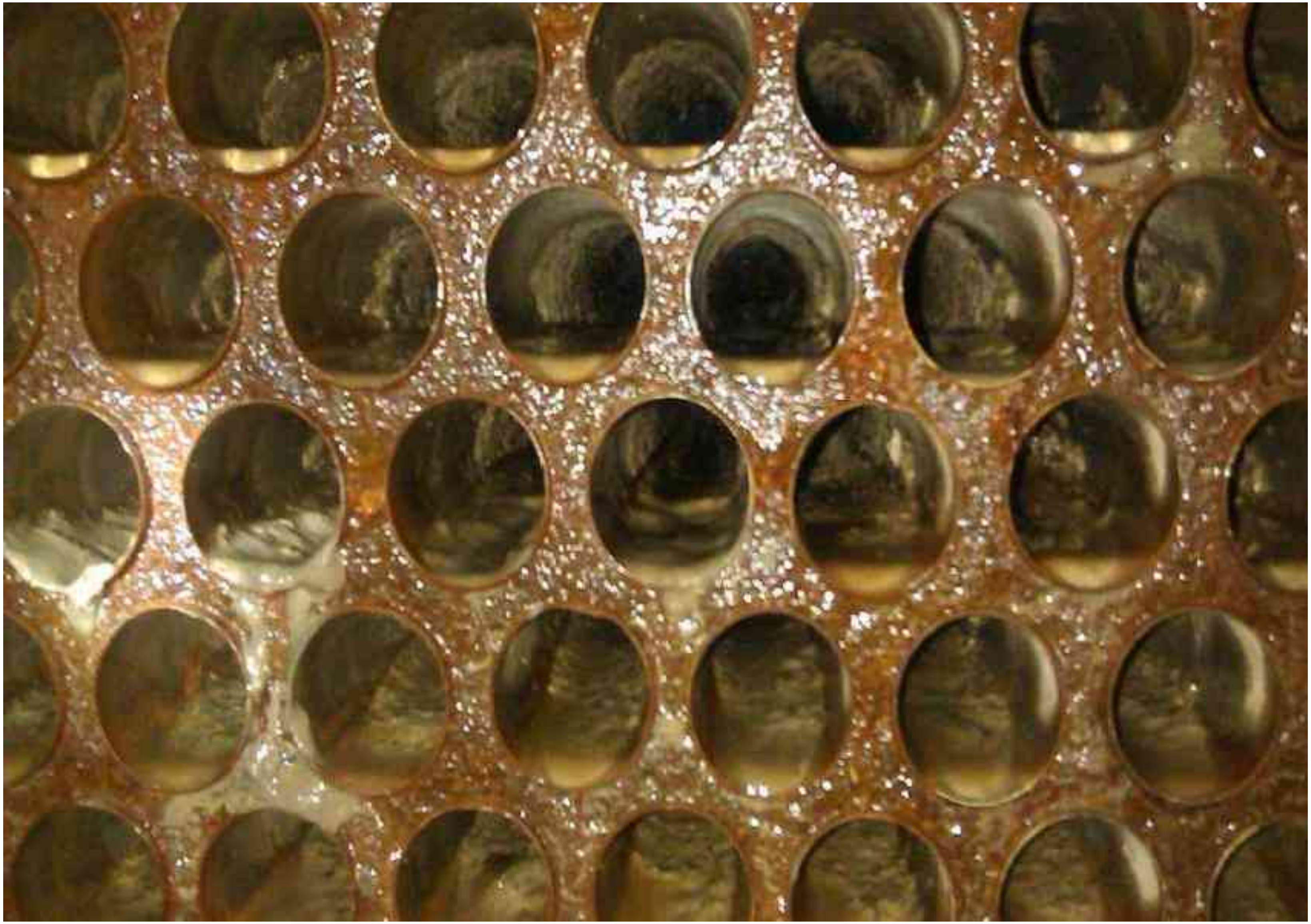


Chemical cleaning circuit in 500 MW unit.

Chemical cleaning circuit in 500 MW unit.

Condenser tubes in 500 MW unit.

Chemical cleaning circuit in 500 MW unit Before Chemical Cleaning.



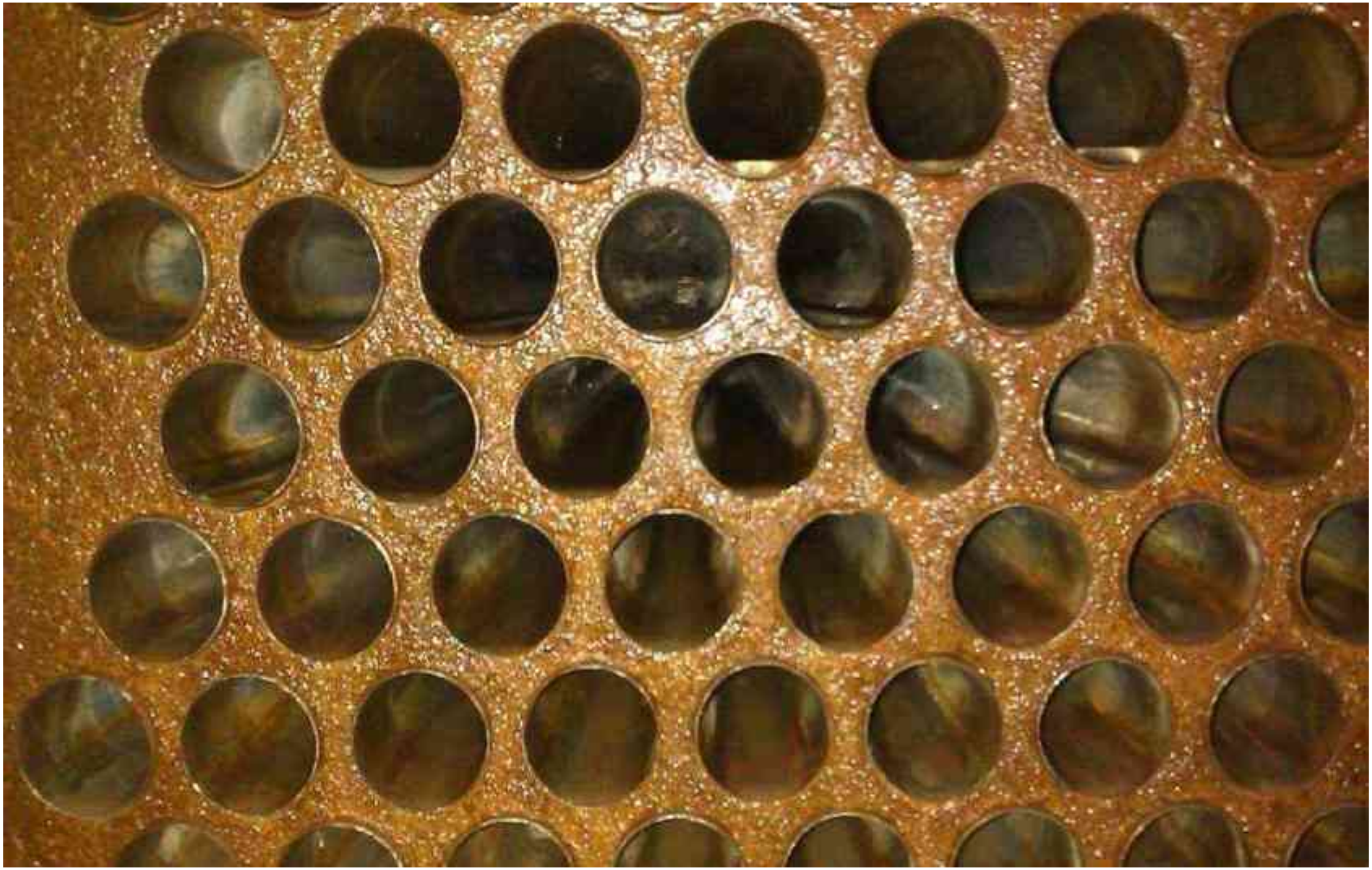
Condenser tubes scale in 500 MW unit.

Simhadari #1

Condenser waterbox in 500 MW unit.

Simhadari #1

Chemical cleaning circuit in 500 MW unit after Chemical Cleaning.



Condenser in 500 MW unit.

Condenser tubes in 500 MW unit.

CONCLUSIONS

- MONITOR ALL PARAMETERS AT THE INLET AND OUTLET REGULARLY
- USE ONLINE MONITORING EQUIPMENT REGULARLY
- USE PROPER CHEMICAL TREATMENT WITH CONTINUOUS ANALYSIS
- USE & OPTIMIZE BIOCIDES AND OTHER CHEMICALS
- WHEREEVER FEASIBLE OPERATE AT HIGHER COC WITH TREATMENT
- WATER QUALITY IS NOT GOING TO IMPROVE IN FUTURE
- PRE-TREAT THE WATER FOLLOWED BY TREATMENT FOR CONTROLLING SCALING, FOULING, CORROSION & BIOFOULING
- MAINTAIN CLEANLINESS ARROUND COOLING WATER SYSTEM

THANKS