WATER CHEMISTRY
&
CORROSION MANAGEMENT
IN
THERMAL POWER PLANT

By- S. Shukla, Sr. Chemist, ABV TPS, Janjgir Champa

➢WHAT IS CORROSION ?

➢It is slow oxidation of metals in presence of moisture and air to form their oxides or hydroxides. For example, rusting of iron.

➢Metal corrosion is a natural and unavoidable phenomenon and is responsible for huge economic loss of a country every year.

➢As per study of NACE International (Leading authority on corrosion in USA), the estimated annual loss caused by corrosion in USA is about 276 billion dollars (Year 2002).

➢FACTORS REQUIRED FOR CORROSION

(1) Air/oxygen

(2) Moisture/Water

(3) Presence of impurities in metal

➢If any of these three factors is missing, corrosion does not occur.

➢In thermal power plants, the water-steam circuits remains constantly in contact with water and therefore, it is inherently prone to corrosion.

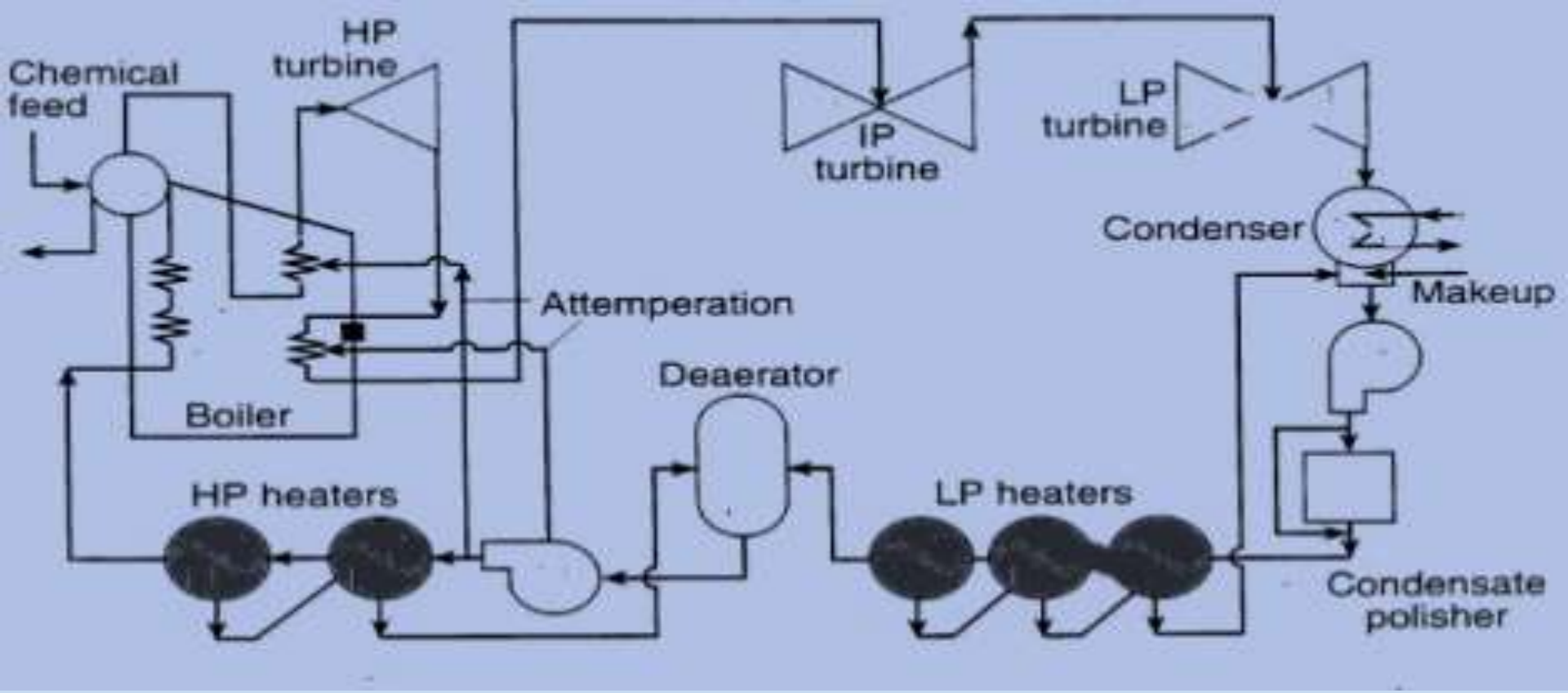


Fig.- Water-Steam Cycle in Power Plant

- Corrosion cannot be checked completely, but it can be controlled and minimized by taking proper preventive measures.
- Hence, to optimize outage of power-generating equipments, prevention of corrosion is very crucial and vital.
- Perfect insulation and protective coatings on the items susceptible to corrosion must be ensured.

- Feed water is principal source of soluble and insoluble impurities entering in boiler.
- Hence, impurities in boiler feed water must be minimized by its efficient deminiralisation, treatment and monitoring.

➢Impurities in Feed water

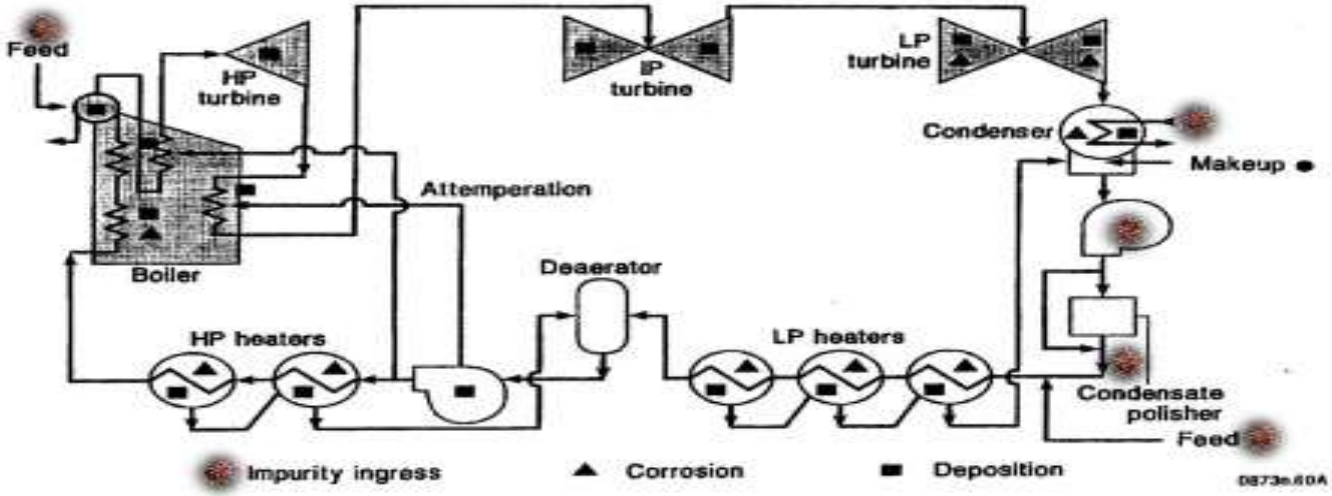
(i)Soluble impurities- These are soluble metal salts that enter in feed water due to leakage of cooling water from condenser and other cooling devices.

➢ It is also due to poor quality of make up water.

(ii)Insoluble impurities- These are mainly metal oxides derived due to corrosion of plant itself i.e. the corrosion of the material of condenser and feed water system.

➢It is minimized by keeping the boiler feed water alkaline and keeping dissolved oxygen to the minimum level.

LOCATIONS OF IMPURITY INGRESS, CORROSION & DEPOSITION - DRUM UNITS



M1-10

➢MOST COMMON CORRODANT IN POWER PLANTS-

(1) Dissolved oxygen

- It plays most important role in metal corrosion. Hence, estimation and removal of dissolved oxygen in feed water, boiler water and condensate is one of the most important control to be exercised to minimize corrosion.
- Dissolved oxygen and other gases are first removed by mechanical deaeration in deaerator. But it does not takes dissolve oxygen within the tolerance limit of 0.005 ppm.

➢Hence, after mechanical removal, residual dissolved oxygen is removed by adding hydrazine in water. It is an oxygen scavenger whose primary function is removal of dissolved oxygen.

$$N_2H_4 + O_2 \rightarrow 2N_2 + 2H_2O$$

➢ Its additional advantages are-

(1) No salt or corrosive substance is formed (liberated N_2 is inert).

(2) At about 270^0C it decomposes to give ammonia which is an alkalysing agent.

$$3N_2H_4 \rightarrow 4NH_3 + N_2$$

(3)Apart from the removal of dissolved oxygen, hydrazine helps in formation of protective magnetite layer in boiler drum.

$$6Fe_2O_3 + 2N_2H_4 \rightarrow 4Fe_3O_4 + 2H_2O + 2N_2$$

➢ Since, removal of dissolved oxygen below tolerance limit of 0.005 ppm is usually not attained, an excess hydrazine reserve (minimum 0.01 ppm) is always maintained in the system.

(2) Free CO_2 in Water

- It is CO_2 dissolved in Water. Its chief source in boiler water, steam and condensate is carbonate and bicarbonate alkalinity in water i.e. M- alkalinity (methyl orange alkalinity).
- The carbonate and bicarbonate undergo thermal decomposition liberating CO_2 which causes corrosion in boiler drum, steam space, super heater tubes and condensate line.

- Neutralization of CO_2 i.e. (H_2CO_3) in boiler is carried out by TSP dosing, while in steam it is done by ammonia dosing to the feed water.
- Ammonia volatilizes with steam and reacts with H_2CO_3 resulting in its neutralization and prevents corrosion.

➢CONSEQUENCES OF CORROSION IN POWER PLANTS-

(1) BOILER TUBE FAILURE-

➢Dissolved oxygen in boiler water causes boiler tubes to oxidize and corrode. It forms grooves within the tubes that lead to cracks and boiler failures.

(2) Prolongs maintenance

(3) Increases operating costs

(4) Reduces efficiency

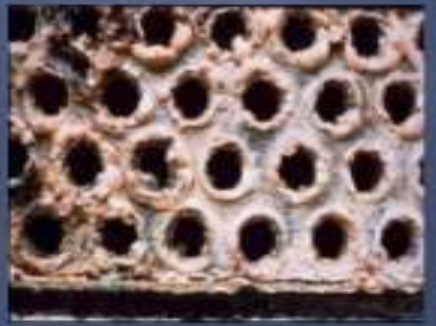
(5) Poses safety risks to the workers.

Typical oxygen pitting of condensate line

Oxygen pitting of a boiler feedwater pipe

- When corrosion affects systems carrying steam or hot water such as pipes, the material or welds may fail causing body injury or even death.
- Industry experts recommend corrosion prevention in the form of preventive and control strategies, such as regular inspections and the use of protective coatings.

CORROSION ,SCALLING, FAULING, AND DEPOSITION

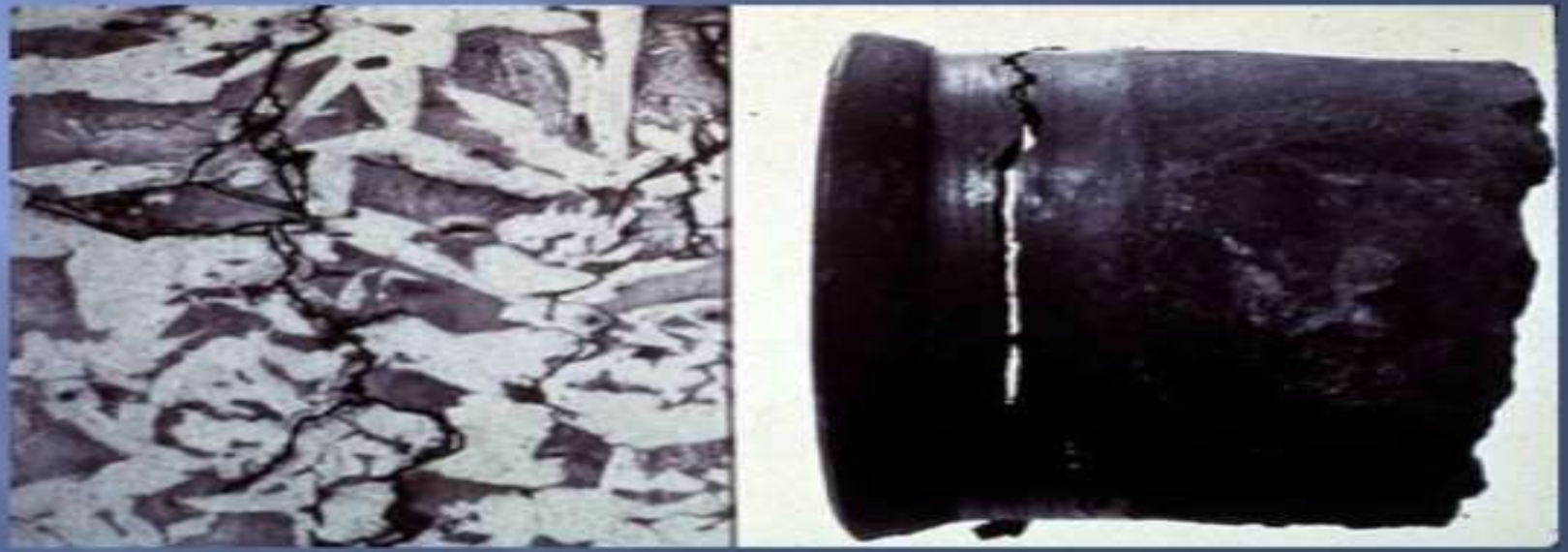


Calcium carbonate scaling in condenser due to poor pH control

Boiler and pre-boiler corrosion

Boiler system tube shows high pH gouging

Caustic stress corrosion cracking (embrittlement) of a boiler tube



Boiler system failure

Thin-lipped burst caused by rapid overheating

Caustic gauging

Caustic reacts with the magnetite and forms sodium ferrite ($NaFeO_2$) and sodium Ferroate (Na_2FeO_2).

Maintain boiler water Phosphate to avoid caustic gauging

➢Power Plant Corrosion- Danger Zones

(1) Hot and cold piping systems

(2)Turbines

(3) Boiler Drum/Boiler tubes

(4) Cooling Towers

(5) ESP Plates

(6) Flue gas inlet ducts/Bypass ducts/Scrubber outlet ducts

- Gases within ducts attack the system physically and chemically.
- Outlet ducts generally have a lower temperature than inlet ducts, making them more susceptible to condensation of moisture and corrosion.

(7) Stacks

- Free standing stacks without windshields or protective liners suffer thermal shock and chemical attacks.

➢Modern trends in Power Generation-

➢Installation of higher and higher pressure boilers.

➢Now a days, in general units of 500 MW or above are being installed and commissioned.

➢The operation of these units require high standard of feed water and steam purity.

➢ Boiler Water Specifications (at 130 kg/cm^2)

pH (At 25^{0}C)	9.2 – 9.5
Conductivity (25^{0}C)	< 50 µS
Total Dissolved Solid	< 25 ppm
Silica	< 0.75 ppm
Phosphate	3 – 6 ppm
Chloride	< 2 ppm
Iron	0.01 ppm
Copper	0.003 ppm
Hydrazine	0.01 – 0.02 ppm

➢ Feed / Steam Water Specifications (130 kg/cm^2)

pH	8.8 – 9.2
Conductivity	0.1 – 0.2 µS
Hardness	Un-detactable
Total Dissolved Solid	< 1 ppm
Silica	0.01 – 0.02 ppm
Iron	0.01 ppm
Copper	0.003 ppm
Hydrazine	0.01 – 0.02 ppm
Dissolved Oxygen	0.007 ppm

➢HOW ARE THESE PARAMETERS MAINTAINED ?

➢**To maintain the parameters of Boiler and other auxilliaries following two types of chemical dosings are carried out-**

(1) TSP Dosing in Boiler Drum (H.P. Dosing)

(2) Dosing of Ammonia & Hydrazine in Deaerator sump/ bfp suction (L.P. Dosing)

➢ROLE OF TSP DOSING

- To maintain pH (Alkalinity) of Boiler (9.2-9.5).
- To stabilize and protect passive magnetite layer of Boiler.
- To prevent Boiler corrosion. It is reserve against an accidental ingress of hardness i.e. condenser tube leakage or ingress with feed water.

- To prevent scale formation by converting ingressed hardness producing salts into sludge especially in case of condenser tube leakage. The calcium and magnesium salts preferentially react with TSP forming a complex sludge instead of sulphate or silicate scales.
- To combat drop in pH at high temperature.

➢ROLE OF AMMONIA DOSING

- To maintain proper pH (Alkalinity) of Pre-Boiler & Steam System (8.5 – 8.8) for the formation, growth and healing of passive Cuprous oxide (Cu_2O) layer.
- Neutralization of CO_2.
- To combat corrosive action of CO_2 in Pre-Boiler & steam system.

➢ROLE OF HYDRAZINE DOSING

- Removal of residual oxygen from Boiler Feed Water (oxygen scavenger).
- Formation, growth and healing of passive Cuprous oxide layer in Pre- Boiler System and Magnetite Layer in Main Boiler System.
- To maintain alkalinity of Water/steam Cycle.

Steam Purity

Recommended parameters of Super heated Steam Purity Guidelines

Parameters	210 MW	500 MW
pH at 25°C	8.8-9.0	**9.0-9.2**
ACC Cond. µm/cm,	0.2	0.2
Silica, ppb, (max)	20	10
Sodium, ppb, (max)	5.0	5.0
NH_3, ppm, (max)	0.5	**1.0**
Total Fe, ppb, (max.)	10	10
Total Cu, ppb, (max.)	5	3

Ref: Code of Practice on Power Plant chemistry, by (OS) COS-ISO-00-OGN-OPS-CHEM/015, Oct.2003

- Solubility of impurities like silica and caustic soda in steam decreases rapidly as it expands in turbine. For example, solubility of NaOH in steam is more than 100 ppb at the temperature and pressure of HP turbine, but it gets highly reduces in LP turbine.
- Decrease in solubility of silica and other impurities results in their deposition on turbine blades and its deterioration.

- **Condenser tube Leakage**
- It is potential source of ingress of impurities in boiler.
- Here, cooling water enters in steam space of condenser.
- **Detection of Condenser tube leakage**

(1)Increase of silica in boiler and condenser.

(2)Hardness would seen in condenser.

(3)Hotwell make up would reduced and level would be high.
(4)Deaerator level would be high.
(5)Conductivity of boiler/condenser sample after cation column gets increased (normal value < 0.2µS/cm.
(6)On line sodium concentration in boiler water gets increased (normal value < 2 ppb).

➢Remidial action-

(1)Opening of CBD.

(2)EBD is recommended if required.

(3)HP dosing (TSP dosing) should be increased to maintain phosphate and free alkalinity in boiler.

(4)CPU flow should be increased.

(5)Load restriction is recommended as per steam requirement.

Drum Pressure Restriction	Reactive Silica in steam (ppm)
60	8.2
80	3.8
100	1.9
120	0.9
130	0.7
140	0.52
145	0.48
150	0.40
155	0.37
160	0.30
165	0.27
170	0.25
175	0.22
180	0.18
185	0.10

➢Condensate Polishing Unit (CPU)

➢It is nothing but a mixed bed installed to purify the return steam condensate in order to meet the requirement of high steam purity in high pressure boiler.

➢It minimizes the consumption of make up water and blow down.

➢It results in cycle clean up of condensate and improves boiler water quality.

➢It helps to take units of full load in lesser time.

THANKS

FOR

WATCHING