

Water Systems: water conditioning for Process and Boiler use

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Introduction

- Industrial water
 - Process water: Water that is used for, or comes in contact with an end product or the materials used in an end product.
 - Boiler feed water
 - Water that serves in any level of the manufacturing process
- Common contaminants: Ca, Mg, Fe, Al, Silica, silt, oil

Impurity		Resulting in	Got rid by
Soluble Gases	H ₂ S	Corrosion of boiler tubes	Aeration, deaeration and chemical treatment
	O ₂		
	CO		
Suspended solids	Sediment and turbidity	Sludge and scale carryover	Clarification, filtration and chemical treatment
	Organic matter	Carryover, foaming and corrosion	
Dissolved colloidal solids	Oil and grease	Foaming, deposition	Coagulation, filtration
	Hardness Ca & Mg	Scaling, inhibits HT, boiler tube burn thru	Softening and internal treatment
	Na, Alkalinity, Na ₂ CO ₃ ,	Foaming, corrosion, embrittlement	Ion exchange, deionization
	Sulphates	Hard scales if Ca present	Deionization
	Chlorides	Priming, foaming	Deionization
	Fe, Mn	Rusting, resistance to HT	Aeration, filtration, ion exchange
	Silica	Scaling	Deionization, lime-soda process

Treatment Methods

- External Treatment
- Internal Treatment

External methods of conditioning

- Clarification
- Filtration
- Ion exchange
- Membrane separation

Clarification

- Removes all types of solids & large particles – sediments, oil, natural org. matter, colour etc.
- Consists of 4 steps – screening, coagulation-flocculation, sedimentation, fine filtration.
- Screening protects downstream units from large, easily separable objects.
- Three types:
 - Fine screening (spacing < 10 mm)
 - Medium screening (spacing 10 – 40 mm)
 - Coarse screening (spacing > 40 mm)
- Coagulation-flocculation removes suspended solids & colloidal particles.

Clarification (contd.)

- Important factors – velocity gradient, time, pH
- Flotation – to separate particles having density lesser than water.
- Three types:
 - Natural
 - Aided
 - Induced
- Induced flotation facilitated through bubbling of air; 2 types –
 - Dissolved air flotation (DAF) (bubbles of 40 – 70 μm)
 - Mechanical flotation (bubbles of 0.2 – 2 mm)

Filtration

- Separates undissolved solids from water by means of a filter - porous substance, membrane or permeable fabric.
- Three types of filtration:
 - Micro filtration (pore size 0.1 – 10 μm)
 - Ultra filtration (pore size 1-100nm)
 - Nano filtration (pore size $< 1 \text{ nm}$)
- Micro filtration – removes bacteria; used for biological wastewater treatment, effluent treatment, separation of oil-water emulsions.
- Ultra filtration - separation of suspended solids, colloids, bacteria, virus.

Filtration (contd.)

- 2 ultra filtration module configurations:
 - Pressurized system or pressure-vessel configuration
 - Immersed system
- Nano filtration – water softening, decolouring, micro-pollutant removal (org. matter, heavy metals, pesticides).
- Ultra & nano filtration – pressure driven processes.
- Pre-treatment – protects filtration membranes;
microfiltration – pre-filter for ultra filtration and so on.

Ion Exchange

- Resins - acidic/basic radicals with ions fixed on them; exchanged with ions present in water.
- Theoretically removes 100 % of salts; does not remove organics, virus or bacteria.
- 2 types of resins – gel type (microporous) and macroporous or loosely cross-linked type.
- 3 systems of resin beds:
 - Strong acid cation + Strong base anion
 - Strong acid cation + weak base anion + Strong base anion
 - Mixed-bed Deionization
- Ion exchange plant – softens water, removes heavy metals, produces demineralized water.

Reverse Osmosis (RO)

- By applying pressure greater than osmotic pressure, water flows from the higher concentration solution to lower one.
- Mostly used for desalination; also for waste water treatment.
- Applied pressure depends on the type and salinity of water.
- Working pressure:
 - < 15 bar for tap water (< 1500 ppm)
 - 15 – 25 bar for brackish water (< 8000 ppm)
 - 50 – 75 bar for sea water (35000 – 45000 ppm)
- RO plant preceded by pretreatment to avoid membrane fouling by sediments, bacteria, metal oxides & chlorine.
- RO permeate water more acidic than the feed water due to dissolved CO₂. Common post-treatment are pH neutralization and remineralization.

Electrodionization

- Combines membrane separation and ion-exchange to provide high efficiency demineralization process.
- Electric potential transports & segregates charged aqueous species.
- Electric current continuously regenerates resin; no need for periodical regeneration.
- Deionization chamber - ion exchange resin, packed between cationic & anionic exchange membranes.

Electrodionization

- Advantages
 - continuous operation
 - eliminates use of chemicals for regeneration
 - low power consumption
- Disadvantages
 - Not used for water with hardness > 1
 - requires purification pretreatment
 - Pre-removal of CO_2

Internal Treatment methods

- Deaerators:
- Dissolved non-condensibles: O_2 and CO_2
- Pitting and corrosion
- Mechanical deaeration: reducing solubility of gases
 - Increased temperature
 - Decreased partial pressure over the water
 - Commonly used purge gas: steam
 - Advantages:
 - No added impurities
 - Easily available
 - Also provides heat
 - Pressure/Vacuum operation, ~98% of total and free is removed
- Coupled with chemical scavengers for complete deaeration

Corrosion control

- pH control
 - Different for different components, different alloys
 - CS : optimum pH = 9.2 to 9.6 at feed water temperatures
 - MS : optimum pH = 8.5 to 12.7 in boilers
 - Cu and CS : 8.8 to 9.2
 - Maintained by addition of amines or small amount of caustic soda
 - Avoidance of addition of ammonia

Corrosion control contd.

- Oxygen control: during operation
 - Chemical Scavengers added to feedwater and condensates
 - Sodium sulfite, bisulfite, hydrazine
 - Quinone, ascorbate
 - Common entry: between deaerator and storage
 - Sodium sulfite:** easy to handle, safe, for pressures of < 70 bar, solid addition to system, decomposition to corrosive gases
 - Hydrazine:** no solid addition, high pressures, but toxic, handling issues, Ammonia liberation, slower reaction
 - Constant sampling and monitoring

Corrosion Control contd.

- Control: downtime and storage
 - Oxygen in-leakage and pH lowering
 - Dry storage: long downtime, month or more
 - Completely dried
 - Applied dessicants like quicklime, silica gel, activated alumina
 - Wet storage: short downtime
 - Cleaning, inspection and filling with deaerated feedwater
 - Addition of scavenger, heat addition

Deposits

- Scaling/deposition from carryover
- Carbonate/Phosphate control
 - Addition of certain amounts of carbonate/phosphate for ensuring precipitate in the form of salts. Prevention of Sulphates
 - For removal of hardness, Ca and Mg
 - Precipitation in bulk instead of at walls, non-adherent
- Organic supplements: fluid sludge formation (polymer addition)
 - Bottom blowdown removes sludge
- Chelant control
- Combination of additives
- Blowdown

Case study -Boiler tube failure

- **Failure mode :Oxygen corrosion**
- **Result: 3-5 shutdowns.**
- **Reasons**
 - Improper deaeration.
 - High level of dissolved oxygen.
 - Leakage in recirculator pump.

Boiler tube failure



Best practices

- **Maintain the equipment properly .**
- **Control the composition of the boiler feed water**
- **Identify optimal chemicals for the prevention of biological growth**
- **Electrically powered water conditioning units**

Best practices-continued

- **Pretreatment of makeup water**
- **Materials of construction**
- **Optimize the frequency of cleaning boilers.**
- **Recent techniques**
 - Magnetic water treatment.

THANK YOU