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Boiler Water Treatment

Theory Training

Boiler Overview

- Steam is the basic energy transfer medium
  - Uses include
    - Residential and commercial heating
    - Plant process steam
    - Plant power generation
    - Utility plant operation
- Critical to the operation of the boiler is water purity
- The components surrounding a typical boiler system include the following:
    - Pretreatment (ion exchange, filtration)
    - Dearator (combined with condensate return)
    - Economizer (heat reuse)
    - Steam management equipment (headers, traps)

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Pretreatment

- Prepare the water to be boiled
  - Calcium and magnesium salts are most insoluble in the hottest areas
- Goal of pretreatment
  - Minimize water use or wastage
  - Minimize chemical use and reduce overall costs
- Common methods
  - Softening - exchange hardness for less harmful ion
  - Lime softening - precipitate hardness
  - Filtration - remove solids
  - Demineralization - exchange all ions for H^+ & OH^-
  - Reverse osmosis - remove all ions to concentrate

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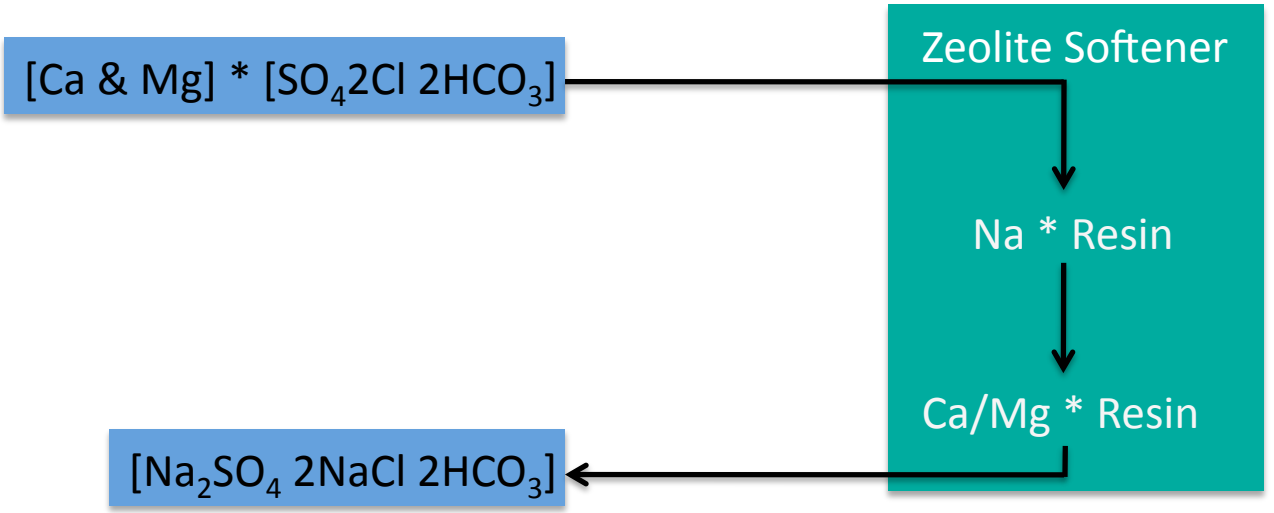
Softening

- Removes hardness in exchange for sodium



- Regenerate softener with sodium chloride
- Hardness problems and consequences
  - Iron fouling, organic fouling, poor regeneration, poor control, damaged internals
  - Increased deposition in boiler, loss of heat transfer

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Deaeration

Based on Dalton's and Henry's Laws of gas solubility in water relating to pressure and temperature.

Deaeration

- Too much oxygen in the boiler causes rust

  $4Fe_3O_4$ (magnetite) + O_2 ⟶ $6Fe_2O_3$ (hematite)

- Can remove this oxygen mechanically or chemically
  - Mechanically
    - Increase temperature driving off oxygen
    - Increase surface area of water driving off oxygen
  - Chemically
    - Sulfite reacts with oxygen to make sulfate in water
    - Organic acid, hydrazine, DEHA, hydroquinone

- Combination of mechanical and chemical means is typical

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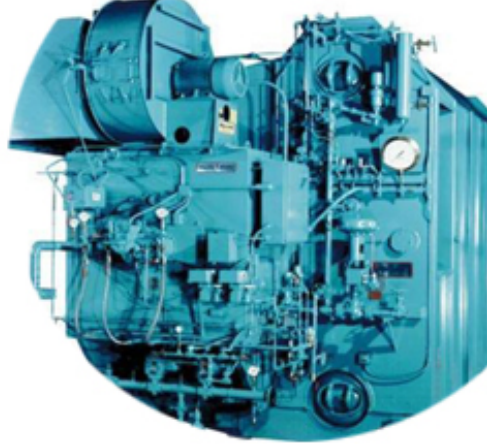
Boiler System



- Firetube boilers
  - Combustion takes place inside tubes
  - Water on shell side, must keep impurities from sticking to the outside of the combustion tubes
  - Mud gravity settles to bottom to be blown down, with steam out the top of the vessel
  - Common packaged systems
- Watertube boilers
  - Water on tube side, tubes consist of risers and downcomers. Steam is on top in the steam drum, with deposits collected in bottom mud drum
  - Several shapes and sizes exist
  - Inspection

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Water Treatment Programs

- In a boiler, mineral content in the remaining boiler water is concentrated; ions do not evaporate
- Cycles of concentration
- Internal boiler water treatment programs
  - Precipitating programs
    - Phosphate based programs
      - $(10Ca^{2}+ 6PO_4^{2-}+ 2OH^{-} \longrightarrow Ca_{10}(OH)_2(PO4)_6)$
      - Analytical testing procedures and review
  - Solubilizing programs
    - All polymer dispersant programs
      - Analytical testing procedures and review
    - Chelant programs
      - Analytical testing procedures and review

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Condense Treatment

- Once steam is used, it is condensed and returned to the feedwater system
  - The more returned the better
    - Savings in make up water, because feedwater is composed of make up and condensate return
    - Savings in heat, with condensate about 140 degrees hotter than makeup, so for 1 lb of water, it takes 140 BTU of energy to get makeup to an equivalent temperature
- The carbon dioxide in steam condenses and can form carbonic acid, unless pH is controlled
- Neutralizing amines
  - They condense in selective locations in the condensate system (near, intermediate, and far)

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Testing Methods

- Analysis of impurities present in water
- Reporting quantities
  - Explanation of parts per million
- Titrations
  - Alkalinity, sulfite, hardness and chlorides
- Colorimetric Tests
  - Phosphate, molybdates
- On-line instrumental tests
  - TDS/conductivity measurement/pH
    - For surface blowdown and condensate

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Test Procedures

- Hardness Test – Softener & Condensate
  1. Measure 100 mL of sample
  2. Add 2 brass dipperful of Hardness Buffer Reagent (Code 291) and stir
  3. Add 1 brass dipperful of Hardness Indicator Reagent (Code 290) and stir. If sample is blue, the water is soft
  4. Add Hardness Titrating Solution drop by drop until color turns blue
  5. Multiply burette reading by 10 to determine parts per million total hardness
  6. Control at less than 1.0 ppm

Test Procedures

- Sulfite Test – Boiler Water
  1. Measure 50 mL of sample
  2. Add 4 drops of Phenolphthalein Indicator (Code 212)
  3. Add 1 plastic dipperful of Sulfite Indicator (Code 219) at a time and stir between each addition. Continue addition until red color disappears, then add one additional dipperful
  4. Slowly add Potassium Iodide-Iodate solution (Code 237). Stir constantly until a faint permanent blue color develops
  5. Multiply burette reading by 10 to determine parts per million sulfite.
  6. Control at 30 – 60 ppm sulfite

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Test Procedures

- Neutralized Conductivity – Boiler Water
  1. To 50 mL boiler water, add 1 mL of Liquid Conductivity Reagent (Code 944) at a time and swirl to mix until colorless
  2. Measure conductivity on Myron conductivity meter
  3. Control at 4000 – 5000 umhos

Test Procedures

- Orthophosphate – Boiler Water
  1. Add 5 mL of filtered sample to mixing tube (Code 152)
  2. Add Molybdate Reagent (Code 236) to second mark (15 mL)
  3. Stopper and mix. Add one brass dipperful of Stannous Reagent (Code 239), stopper and mix well
  4. Place mixing tube in viewing compartment, compare, and record result
  5. Control at 30 – 60 ppm phosphate

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Test Procedures

- Hydroxyl Alkalinity – Boiler Water
  1. Fill mixing cylinder to 25 mL mark with boiler water
  2. Add 1 mL barium chloride solution, swirl to mix
  3. Add 2 drops Phenolphthalein indicator, swirl to mix
  4. Add sulfuric acid reagent one drop at a time, until color changes from pink to clear
  5. Multiply number of drops times 50
  6. Control at 200 – 400 ppm (4 – 8 drops) hydroxyl alkalinity

- pH – Condensate
  1. Use pH meter, control at pH 8.2 – 8.8

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Safety Precautions

- Handling boiler water treatment chemicals
- Sampling steam generating systems
  - Boiler water sampling
  - High purity steam sampling
    - Sampling quill explanation
  - Condensate sampling
  - Cooling coil explanation and discussion
- Boiler house safety concerns
- Analytical testing precautions
  - Reagent handling
  - Handling precautions

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Review Quiz

- Why do we worry about hardness (calcium and magnesium) in the boiler?
- What are the two ways that hardness is managed (in makeup and boiler water)?
- What effect does oxygen have on the boiler?
- If makeup calcium is 1 ppm, and the boiler is running at 20 cycles of concentration, how many ppm calcium is in the boiler water?
- What two pieces of safety equipment should you have when handling chemicals?

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