

Water treatment for boilers

TNO | Knowledge for business



Water treatment

Questions

- Why do we need to control the water quality
- What is the relationship between blowdown and water quality?
- What is measured daily around the steam production and distribution?
- How does soot influence efficiency?

Benefits of water treatments

- Increase boiler efficiency
- Reduce fuel, operating and maintenance costs
- Minimize maintenance and downtime and
- Protect equipment from corrosion
- Extend equipment lifetime

Order

- Problems
- Causes
- Solutions
 - External treatment
 - Chemical treatment
 - Blowdown

(eat good stuff, live healthy)

(use medicine and vitamin pills)

(incurable, regular visits to hospital)

Problems that will effect boiler performance:

- Scale formation
- Corrosion
- Fouling
- Foaming
- Embrillement

- Problems
- Causes
- Solutions



Scaling

- Scale acts as an insulator that reduces heat transfer, causing a decrease in boiler efficiency and excessive fuel consumption.
- More serious effects are overheating of tubes and potential tube failure (equipment damage).
- Fuel wasted due to scale may be approximately 2-5 percent depending on the scale thickness.



- Problems
- Causes
- Solutions

Corrosion

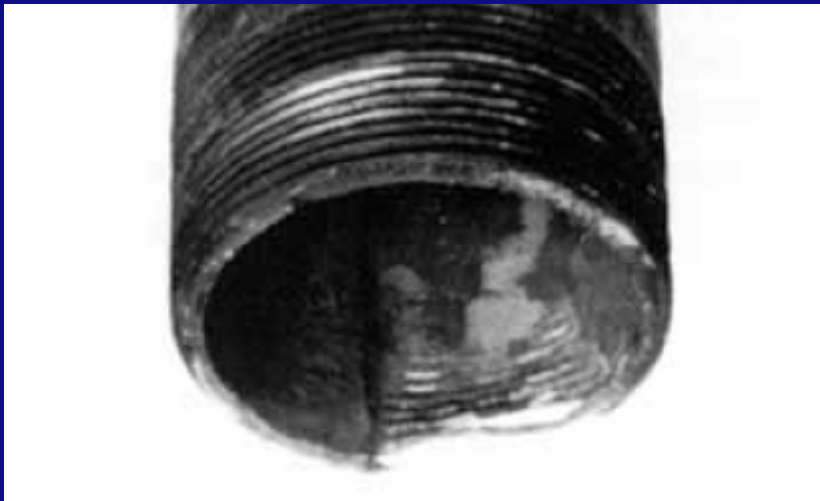
- Oxygen pitting corrosion, seen on the tubes and in the preboiler section
- Low pH corrosion, seen in the condensate return system
- Leads to
 - failure of critical parts of the boiler system,
 - deposition of corrosion products in critical heat exchange areas and
 - overall efficiency loss
- Active oxygen pits can be distinguished by the red-brown tubercle which, when removed, exposes black iron oxide within the pit.

- Problems
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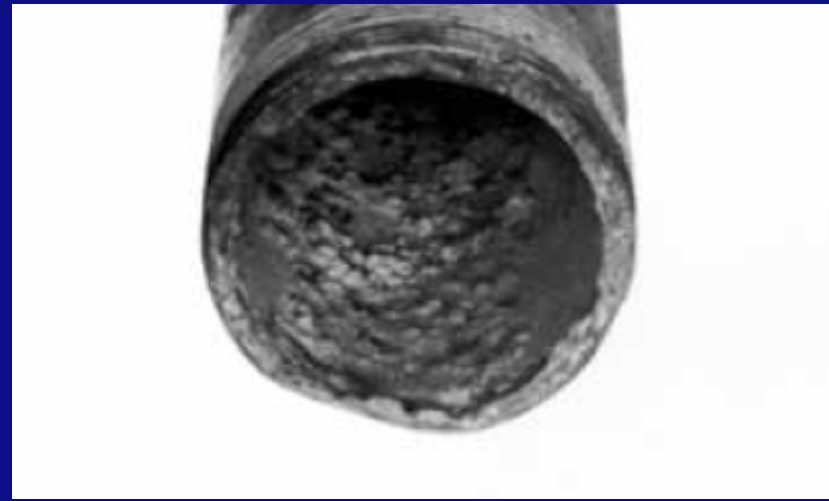


Influence of gasses

- Oxygen speeds corrosion
- CO₂ creates carbonic acid: highly corrosive



Damage by carbonic acid



Damage by corrosion

- Problems
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Caustic embrittlement

- will occur when there is a high concentration of alkaline salts (a pH value of 11 or greater) that will liberate hydrogen absorbed by the iron in the steel. Caustic embrittlement will be more evident in high temperature areas of the boiler's waterside and manifests itself in the form of hairline cracks.

- Problems
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Carryover

- Caused by either priming or foaming
 - *Priming* is the sudden violent eruption of boiler water, which is carried along with steam out of the boiler
 - Can cause deposits in and around the main steam header valve in a short period of time
 - *Foaming* causes carryover by forming a stable froth on the boiler water, which is then carried out with the steam.
 - Over a period of time, deposits due to foaming can completely plug a steam or condensate line.

- Problems
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List Of Problems Caused By Impurities In Water

Impurity (Chemical Formula)	Problems	Common Chemical Treatment Methods
Alkalinity (HCO_3^- , CO_3^{2-} and CaCO_3)	Carryover of feedwater into steam, produce CO_2 in steam leading to formation of carbonic acid (acid attack)	Neutralizing amines, filming amines, combination of both, and lime-soda.
Hardness (calcium and magnesium salts, CaCO_3)	Primary source of scale in heat exchange equipment	Lime softening, phosphate, chelates and polymers
Iron (Fe^{3+} and Fe^{2+})	Causes boiler and water line deposits	Phosphate, chelates and polymers
Oxygen (O_2)	Corrosion of water lines, boiler, return lines, heat exchanger equipments, etc. (oxygen attack)	Oxygen scavengers, filming amines and deaeration
pH	Corrosion occurs when pH drops below 8.5	pH can be lowered by addition of acids and increased by addition of alkalis
Hydrogen Sulfide (H_2S)	Corrosion	Chlorination
Silica (SiO_2)	Scale in boilers and cooling water systems	Lime softening

- Problems
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Common impurities in water

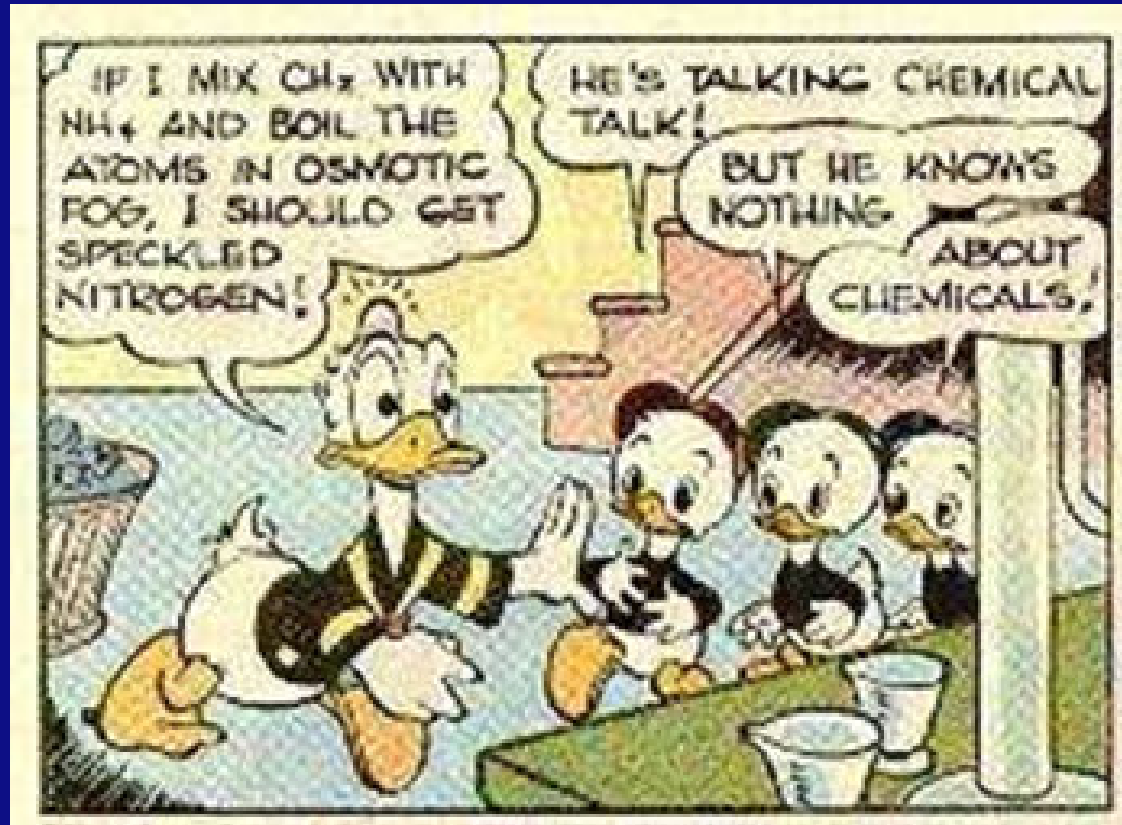
- alkalinity,
- silica,
- iron,
- dissolved oxygen and
- calcium and magnesium (hardness)

- Problems
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In chemical terms

- Sludge (TSS)
- ppm CaCO_3
- TDS, Silica
- dissolved oxygen
- sodium
- potassium
- sulphate
- chloride
- total hardness (TH)



- Problems
- Causes
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Acid attack, Alkalinity

- Causes of corrosion.
- Happens when the pH of feed water drops below 8.5.
The carbonate alkalinity in the water is converted to carbon dioxide gas (CO_2) by the heat and pressure of the boilers. CO_2 is carried over in the steam. When the steam condenses, CO_2 dissolves in water to form carbonic acid (H_2CO_3) and reduces the pH of the condensate returning to the boilers.
- Acid attack may also impact condensate return piping throughout the facility

- Problems
- Causes
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Scaling

- Precipitation of normally soluble solids that become insoluble as temperature increases
- Examples: calcium carbonate, calcium sulphate, and calcium silicate



- Problems
- Causes
- Solutions



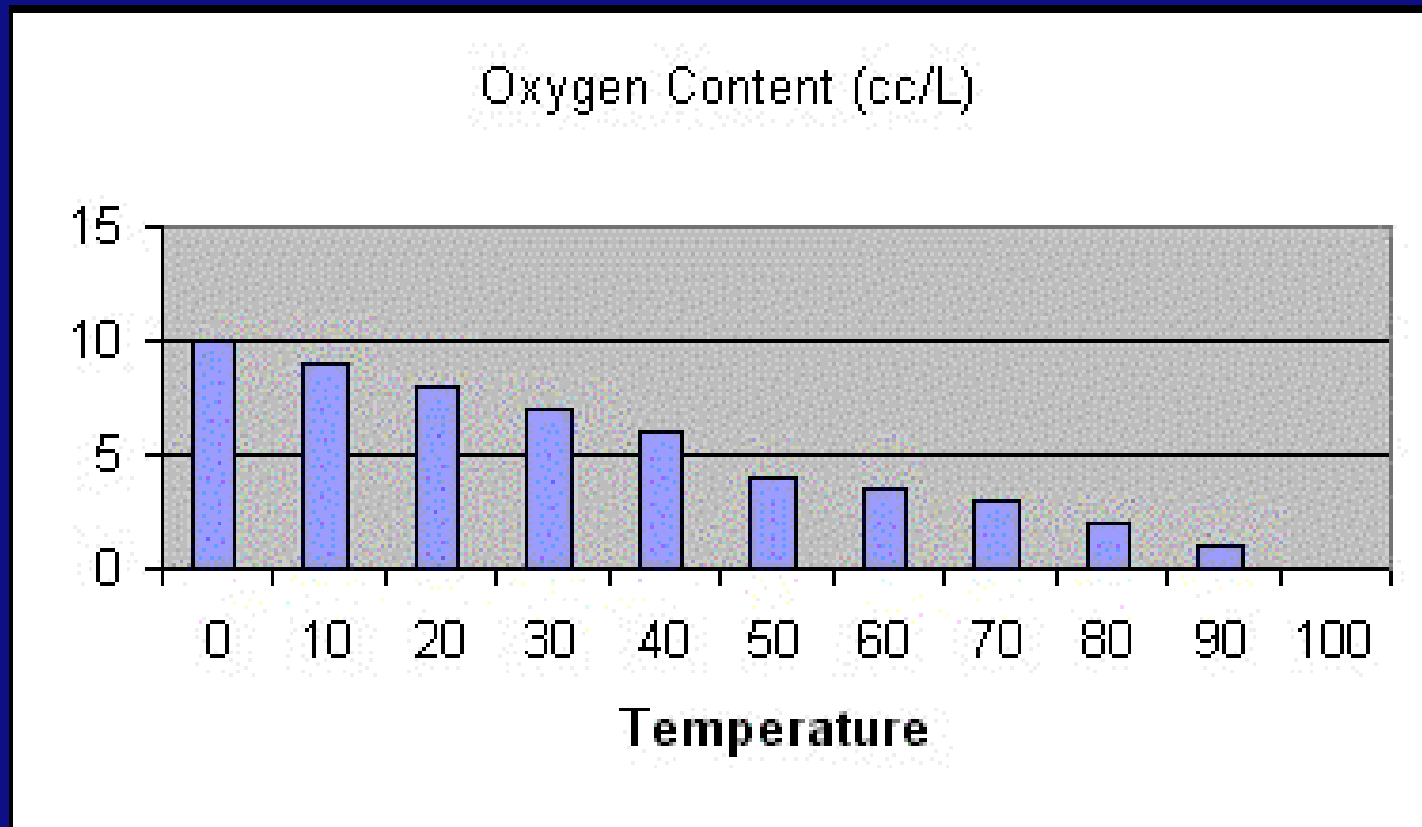
Dissolved oxygen in feed water

- Can become very aggressive when heated and reacts with the boiler's internal surface to form corrosive components on the metal surface.
- Oxygen attack can cause further damage to steam drums, mud dams, boiler headers and condensate piping.

- Problems
- Causes
- Solutions



Oxygen content of water



- Problems
- Causes
- Solutions

Impurity Source Effect

• Algae	organic growth	fouling
• Calcium	mineral deposits	scale
• Carbon dioxide	dissolved gases	corrosion
• Chloride	mineral deposits	corrosion
• Free acids	Indus. Wastes	corrosion
• Hardness	mineral deposits	scale
• Magnesium	mineral deposits	scale
• Oxygen	dissolved gases	corrosion
• Silica	mineral deposits	scale
• Suspended solids	undissolved matter	fouling/scale

- Problems
- Causes
- Solutions



Solution

- External treatment
- Chemical treatments
- Blowdown

- Problems
- Causes
- Solutions

- External
- Chemical
- Blowdown



External treatment

- Clarification
- Filtration
- Softening
- Dealkalization
- Demineralization
- Deaeration
- Heating

- Problems
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ASME Guidelines for Water Quality

Drum pressure 0-300 psi

- **Boiler Feedwater**

- Iron (ppm Fe) 0.1
- Copper (ppm Cu) 0.05
- Total Hardness (ppm CaCO_3) 0.3

- **Boiler Water**

- Silica (ppm SiO_2) 150
- Total Alkalinity (ppm CaCO_3) 700
- Specific Conductance (micromhos/cm)
(unneutralized) 7000

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Boiler feedwater norms

Parameter	0-20 kg/cm ²	21-40 kg/cm ²	41-60 kg/cm ²	Purpose to prevent:
pH	8.5-9.5	8.5-9.5	8.5-9.5	Corrosion
Oxygen	0.05	0.02	0.01	Pitting
Total hardness	<10	<2	<0.5	Scaling
Silica	-	5	0.5	Scaling

Source: Thermax Limited Chemical Division

- Problems
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Boiler water norms

Parameter	0-20 kg/cm ²	21-40 kg/cm ²	41-60 kg/cm ²	Purpose to prevent:
pH	11-12	11-12	10.5-11	Corrosion
Total hardness	ND	ND	ND	Scale
Total alkalinity (20% of TDS)	700	500	300	Foam
Caustic alkalinity	300	150	60	Foam
Silica (<40% of caustic alkalinity)	<120	<60	<24	Scale
TDS	3500	2500	1500	Corrosion
Phosphates	20-40	15-30	5-20	Corrosion
Sulphite	30-50	20-40	-	Oxygen
Hydrazine	0.1-1.0	0.1-0.5	0.05-0.3	Oxygen

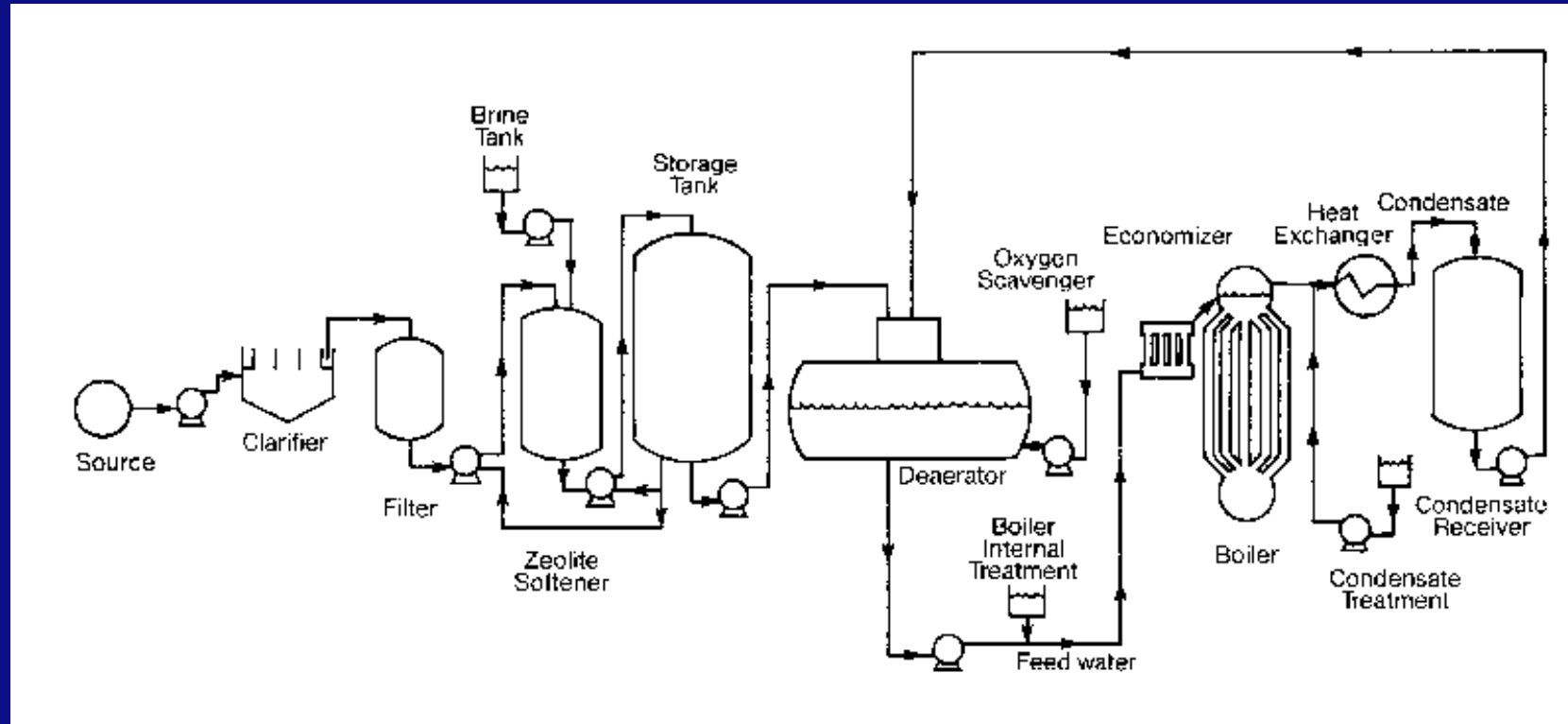
Source: Thermax Limited Chemical Division

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Water treatment equipment



- Problems
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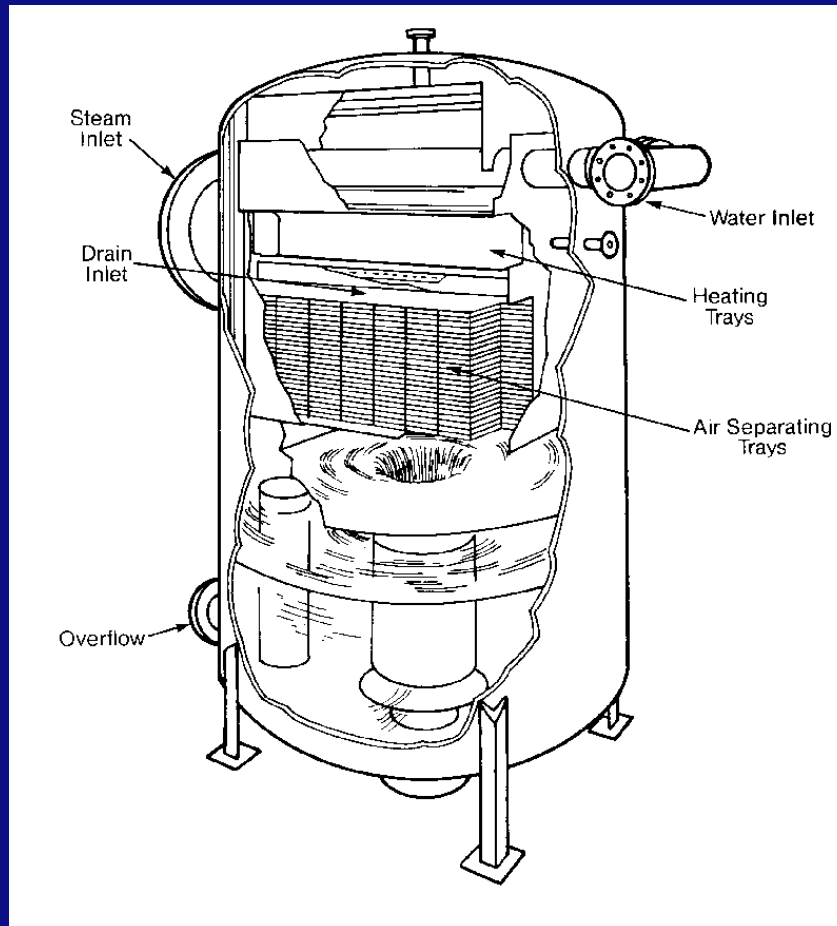
Dealkalization (solves acid attack, alkalinity)

- Dealkalization is the process in which softened water is passed through a treatment tank that contains an anion resin. This anion resin removes anions such as sulfate, nitrate, carbonate and bicarbonate. These anions are then replaced by chloride. Sodium chloride (salt) is then used to regenerate the unit with the anion exchange resin.

Purposes of deaeration

- Remove oxygen, carbon dioxide and other non-condensable gases from feed water
- Heat the incoming makeup water and return condensate to an optimum temperature for:
 - minimizing solubility of the undesirable gases
 - providing the highest temperature water for injection to the boiler

Tray-type deaerating heater (Cochrane Corp.)

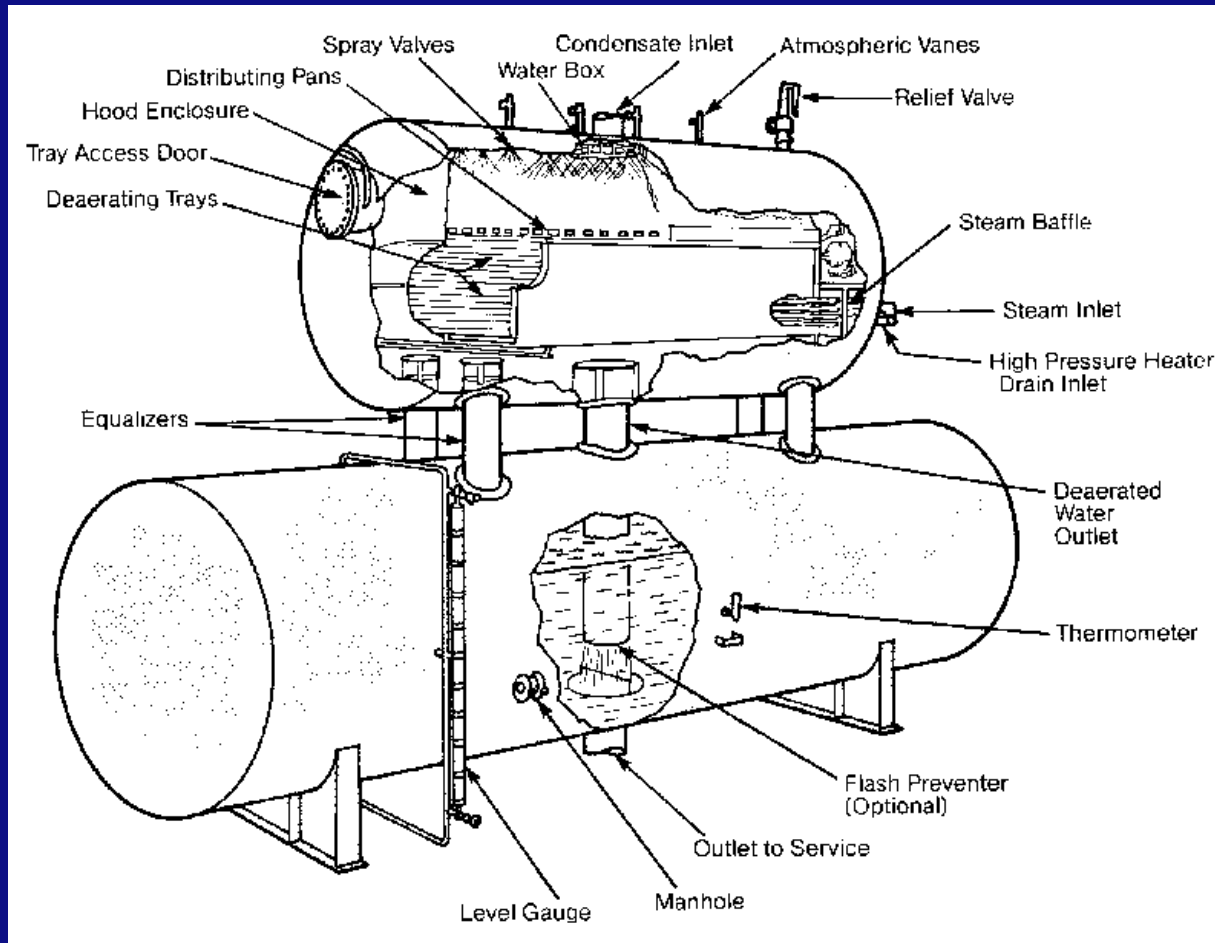


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Tray-type deaerating heater (Graver)



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Deaerating heater troubleshooting guide

Symptom	Remedy
Excessive oxygen content in deaerator effluent	1. Insufficient venting-increase vent rate by opening the manually operated air vent valve.
	2. Check steam pressure reducing valve for improper operation and hookup. Check valve for free operation, and see that control line is connected to the connection provided in the deaerator and not to the piping downstream of the valve.
	3. Check water and, if possible, steam flow rates vs. design. Trays or scrubber and inlet valves are designed for specific flow ranges.
Temperature in storage tank does not correspond within 5 ° F of saturation temperature of the steam	1. Improper spray from spray nozzle. Check nozzle for sediment or deposit on seat or broken spring.
	2. Excessive free air due to leaking stuffing boxes on pumps upstream of deaerator that have negative suction head. Repair stuffing box or seal with deaerated water.
Excessive consumption of oxygen scavenger	1. Trays collapsed-possibly from interrupted steam supply or sudden supply of cold water causing a vacuum.
	2. Condensate may be too hot. Water entering the de-aerating heater must usually be cooled if the temperature is within 20 ° F of saturation temperature of the steam. Check the design specification to determine what inlet water temperature was originally intended.
High or low water level	1. Improper operation of inlet control valve. Adjust as necessary.
	2. Check faulty operation of steam pressure reducing valve.
	3. Check relief valves on the deaerator and in the main steam supply system for proper operation.
Low pressure	1. Check for improper operation of steam pressure reducing valve.



Measurement of Dissolved Oxygen



Measurement of Dissolved Oxygen

- *Indigo Carmine*

A colorimetric procedure for determining dissolved oxygen in the 0 to 100 ppb range. Standards are also available for high range (0-1 ppm),

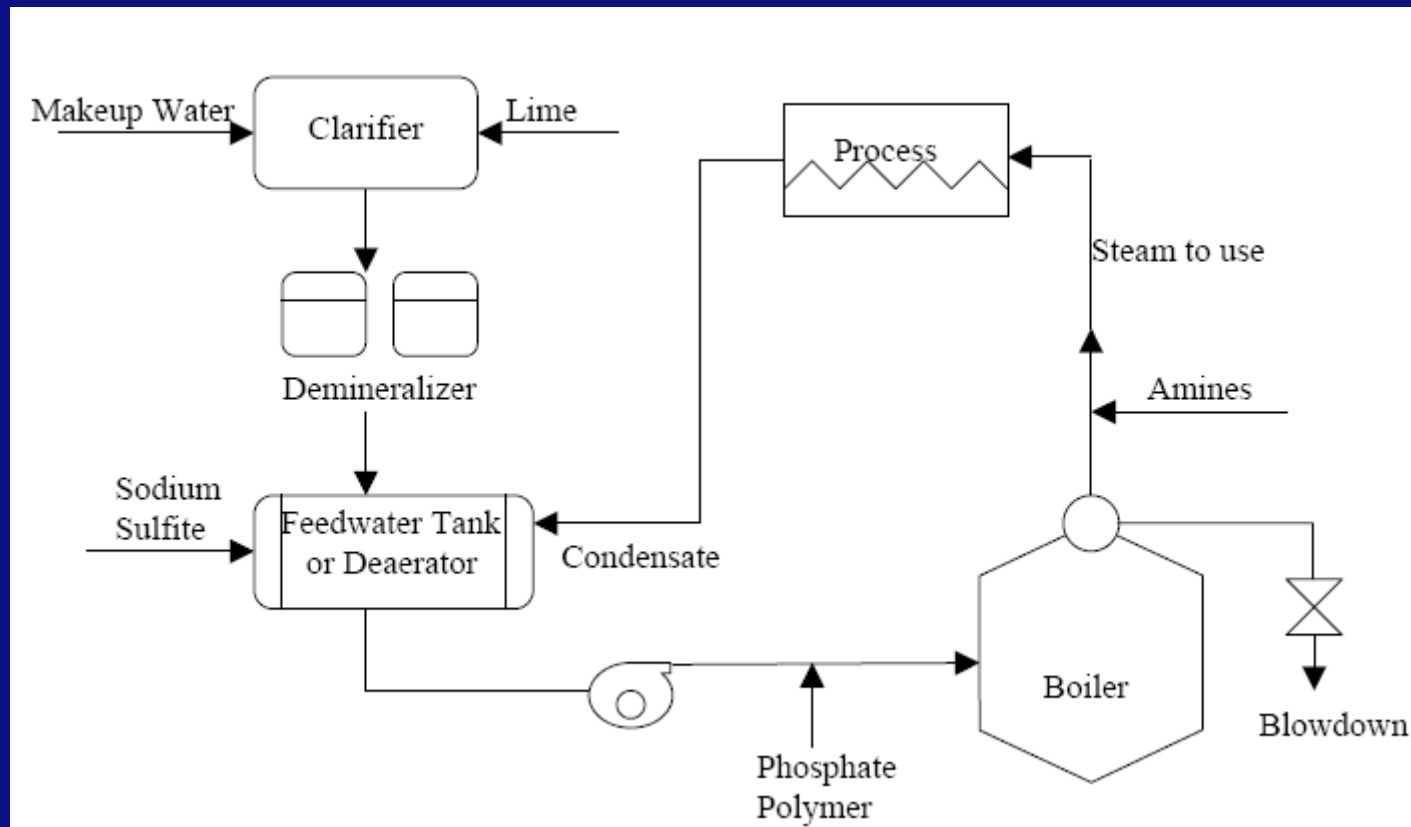
- *Ampulmetric*

This test offers ease of operation and minimum time in collecting reliable data. Capsules are available in the 0-100 ppb and 0-1 ppm range.

- *Oxygen Analyzers*

Offers accurate reliable direct measurement in liquid streams. Used to monitor dissolved oxygen continuously or intermittently at various points in the condensate and feedwater systems.

Chemical treatment



Phosphate reduces hardness, 40-80 mg/l
Sodium sulfite, oxygen scavenger
Amines, pH control, CO₂ reduction

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Oxygen scavengers

- Volatile products
(e.g., hydrazine, or other organic products like carbohydrazine, hydroquinone, diethylhydroxyethanol, methylethylketoxime, etc.)
and
- Non-volatile salts
(normally: sodium sulphite, Na_2SO_3 , or a derivative thereof).
Contain catalysing compounds to increase of rate of reaction with dissolved oxygen (e.g., cobaltous chloride).
- Hydrazine (N_2H_4) is seriously toxic and great care should be taken in its handling

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Blowdown

- Needed to lower TDS

Total dissolved solids (TDS)

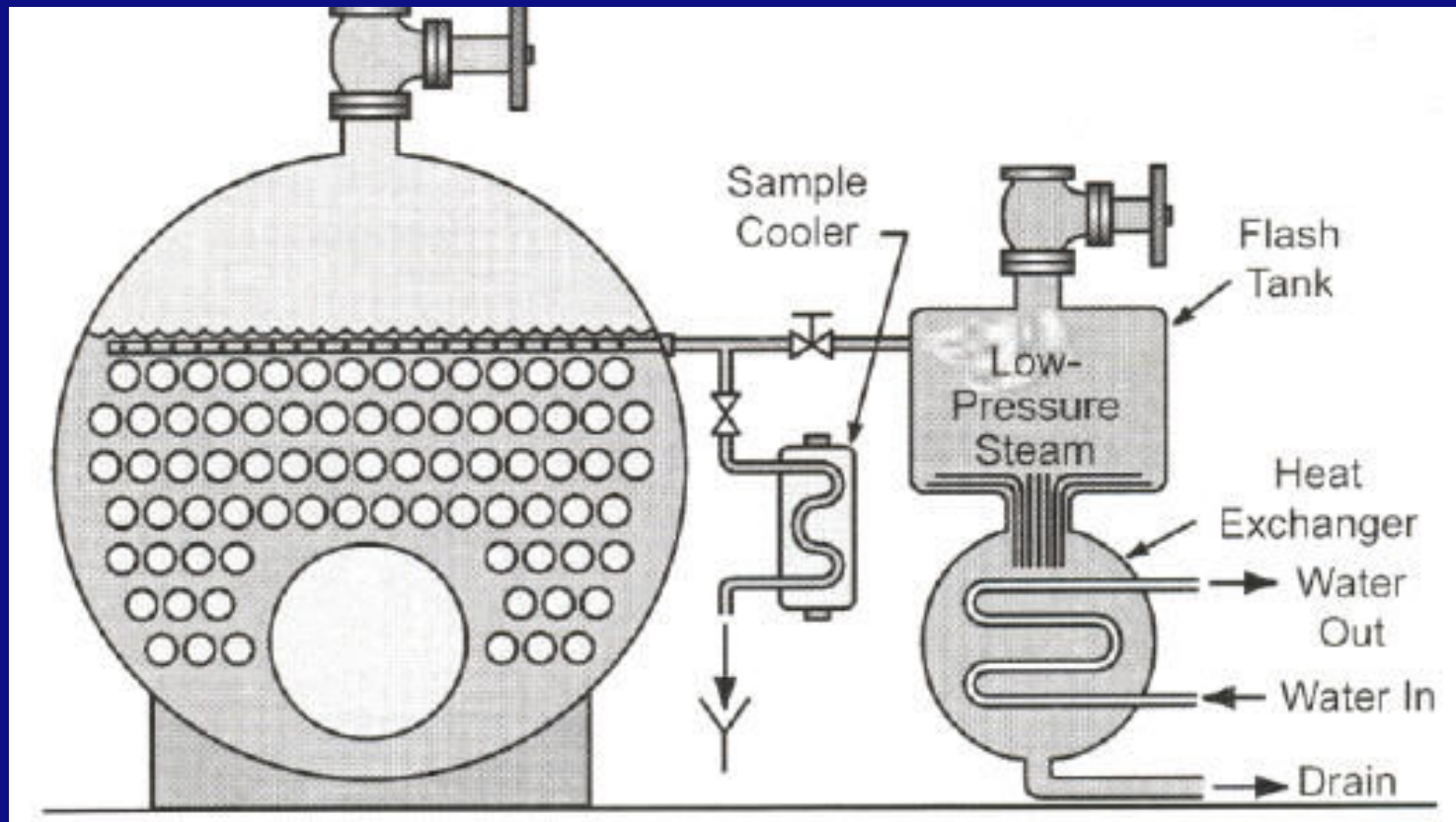
- Sum of all minerals or ions in the water
 - **Insoluble iron** can clog valves and strainers and can cause excessive sludge build up in low lying areas of a water system.
 - It also leads to boiler deposits that can cause tube failure.
 - **Soluble iron** can interfere in many processes, such as printing or the dying of cloth.
 - **Water Hardness** is the measure of calcium and magnesium content as calcium carbonate equivalents.
 - Water Hardness is the primary source of scale in boiler equipment.
 - **Silica** in boiler feedwater can also cause hard dense scale with a high resistance to heat transfer.
 - **Bases**, especially bicarbonates and carbonates, break down to form carbon dioxide in steam, which is a major factor in the corrosion of condensate lines. Alkalinity also contributes to foaming and carryover in boilers.

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Flash tank

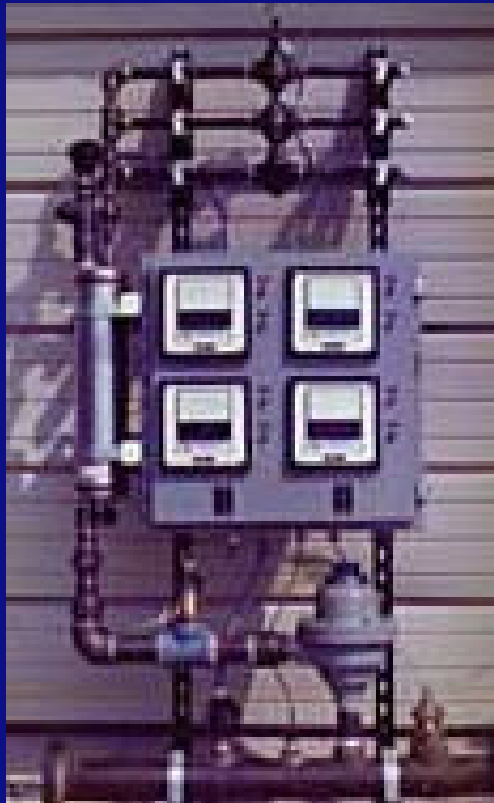


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TDS control

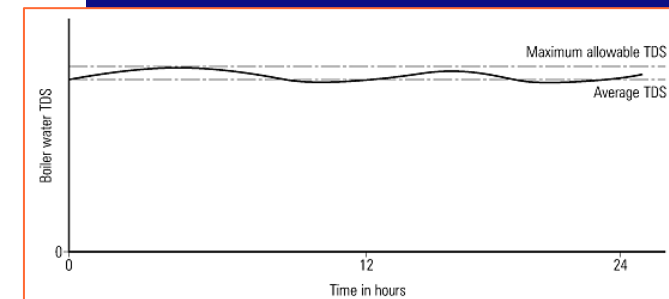
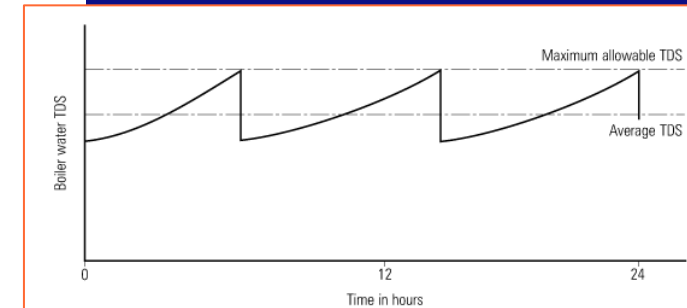
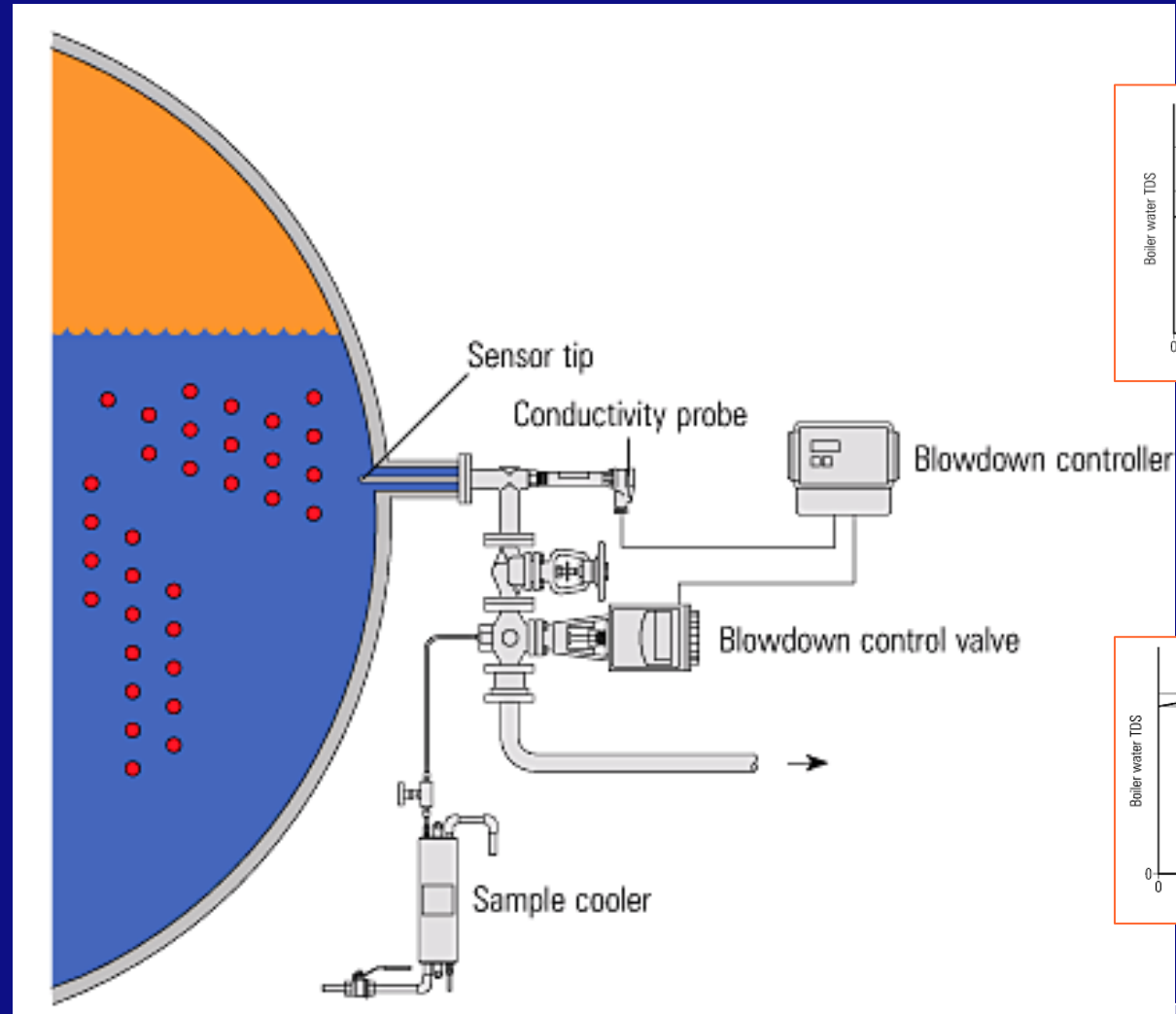


TDS monitor and blow down control

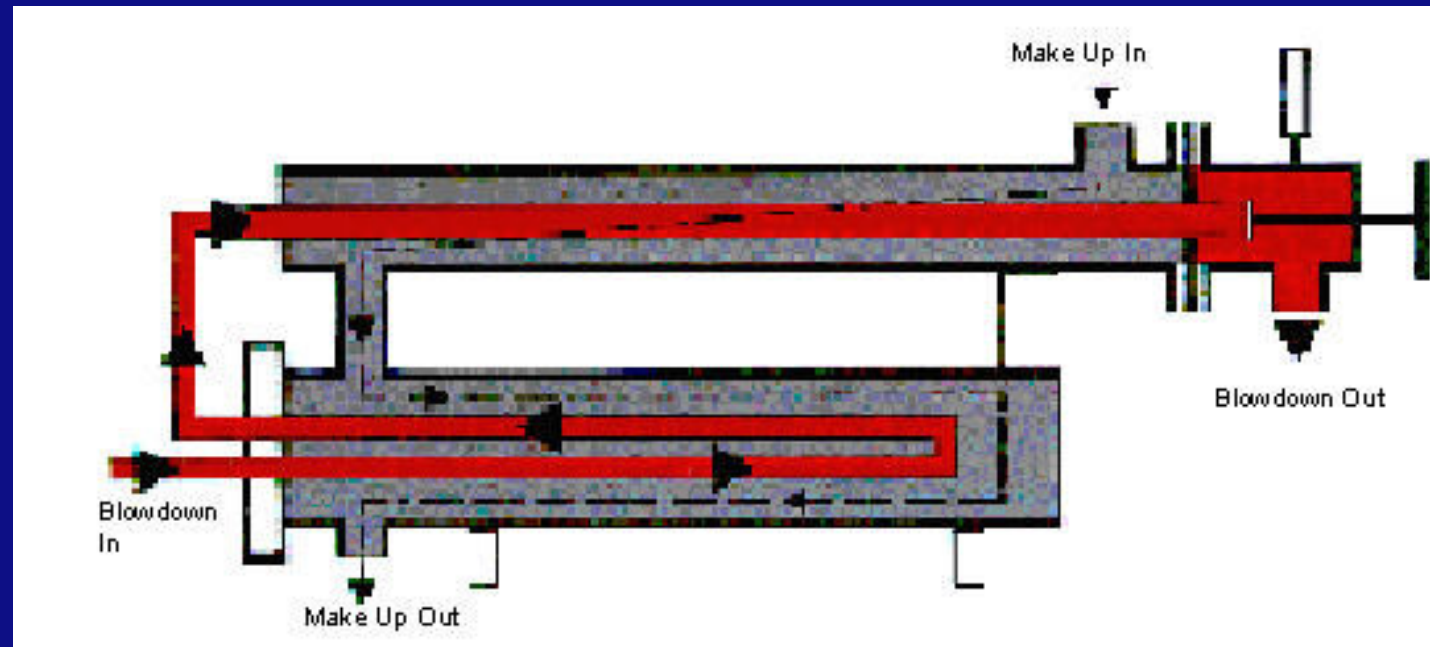


Water sample cooler

Electronic TDS control system



Heat exchanger blow down



Poor treatment performance can create domino effects increasing operating and maintenance costs

Advice:

- Understand the problems and different treatment methods.
- Evaluate the overall cost and benefits.
Selecting a program solely on the basis of the lowest cost is false economy.
- Have a qualified water chemist to monitor and ensure consistent water quality.
- Review blowdown practices to identify energy saving :
 - Minimizing blowdown rate can significantly reduce energy losses.
 - However, insufficient blowdown may lead to carryover of boiler water into the steam and formation of deposits.

Points for daily recordings

- Water Level
- Low Water Cut Off Tested
- Blowdown Water Column
- Blowdown Boiler
- Visual check of Combustion
- Boiler Operating Pressure/Temperature
- Feedwater Pressure/Temperature
- Condensate Temperature
- Feedwater Pump Operation
- Flue Gas Temperature
- Gas Pressure
- Oil Pressure and Temperature
- General Boiler/Burner Operation

Idea

- Increase condensate return
- Avoid direct injection
- Avoid leakage
- Use RO water for boiler

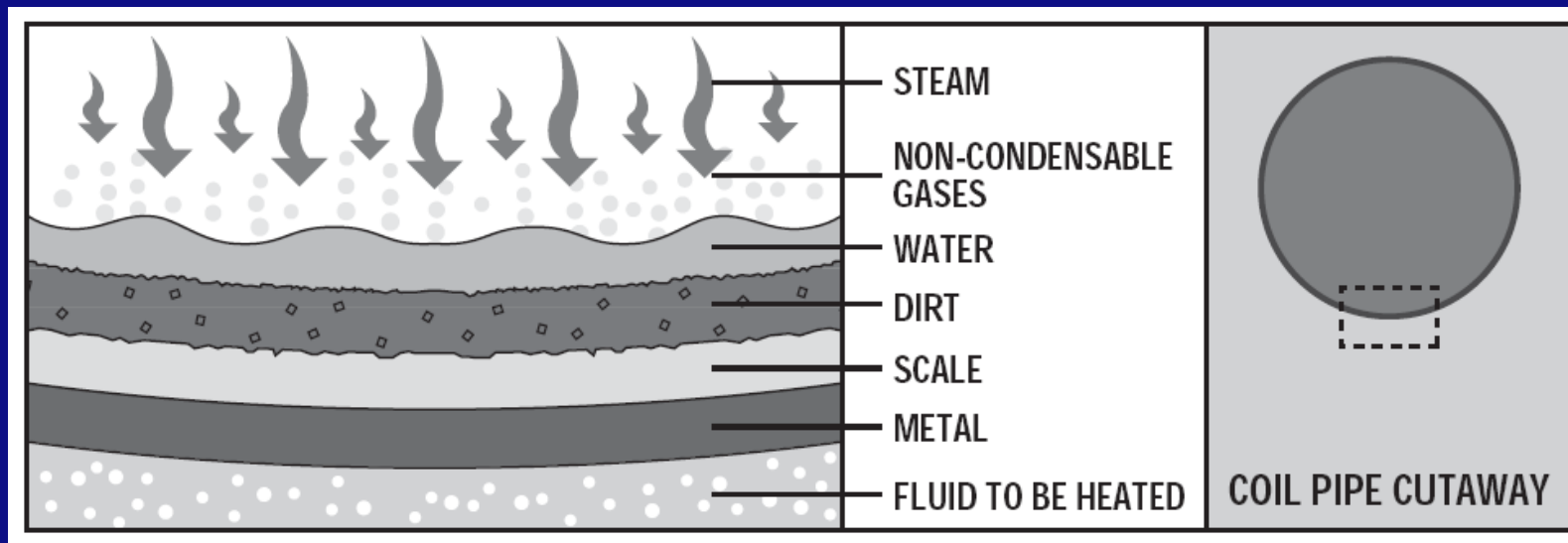
Flue gas

Soot

- Soot is caused by improper and incomplete combustion
- Soot is a soft black substance that can build up on the boiler fireside tube surface.
- Similar to scale buildup on the waterside surface, soot inhibits heat transfer, hence reducing boiler efficiency.
- A layer of soot of only 1/8 inch in thickness can reduces boiler efficiency by approximately 8.5 percent.

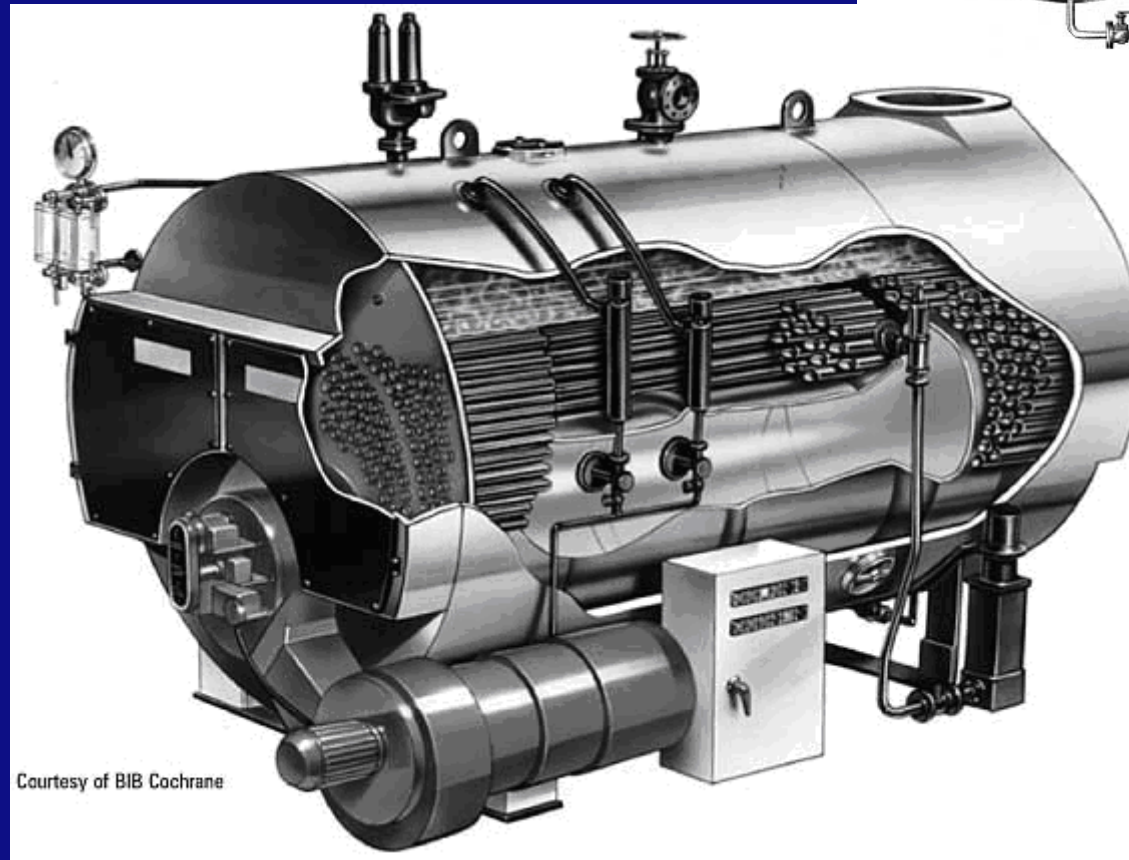
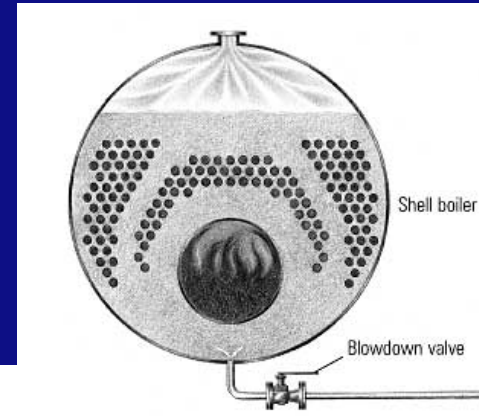


Dirt and scale negative influence on efficiency heat exchanger

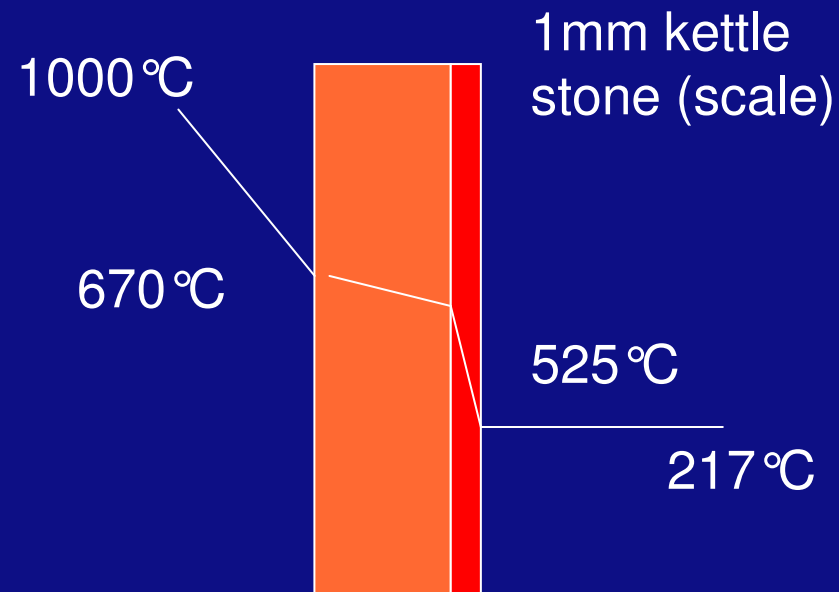
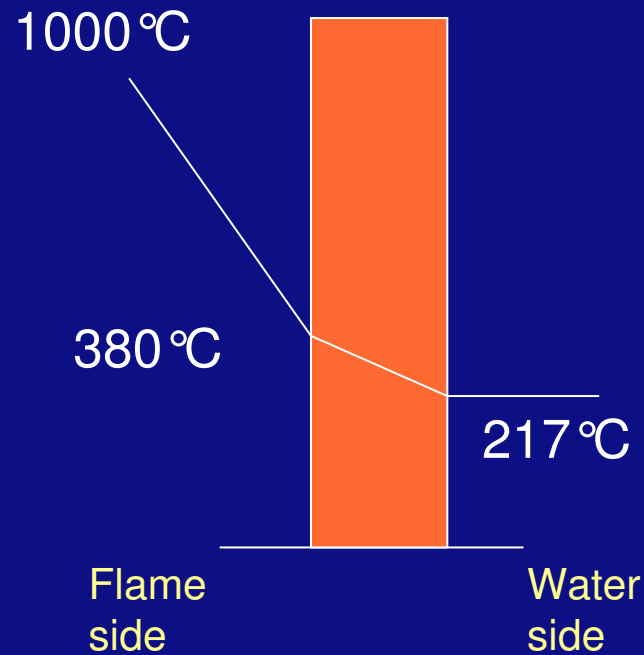
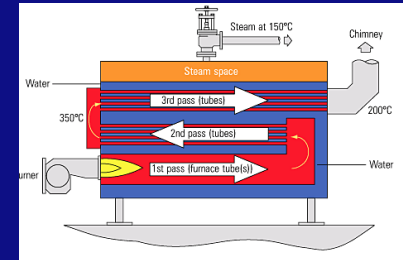


Boiler as heat exchanger

- Flame pipes



Temperatures flame pipes in boiler



Flue gas analysis

