Boiler Water

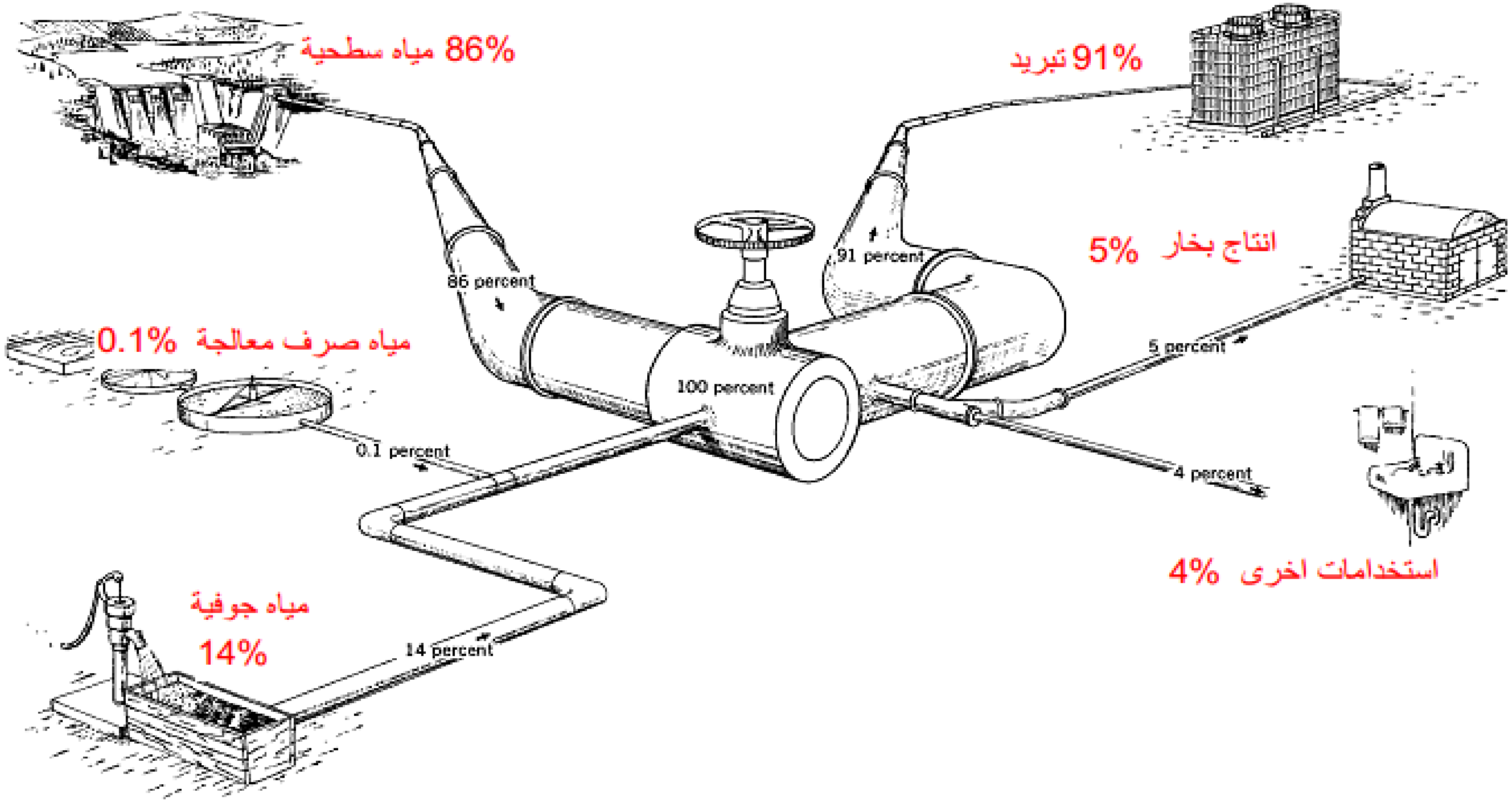
By: Eng. Ahmed Hamdy

Industrial Water Orientation

Industrial Water Exposed to Severe Conditions

Industry Water Sources and Uses

Sources **Industrial Uses**



مصادر واستخدامات المياه بالصناعه

What is in Water

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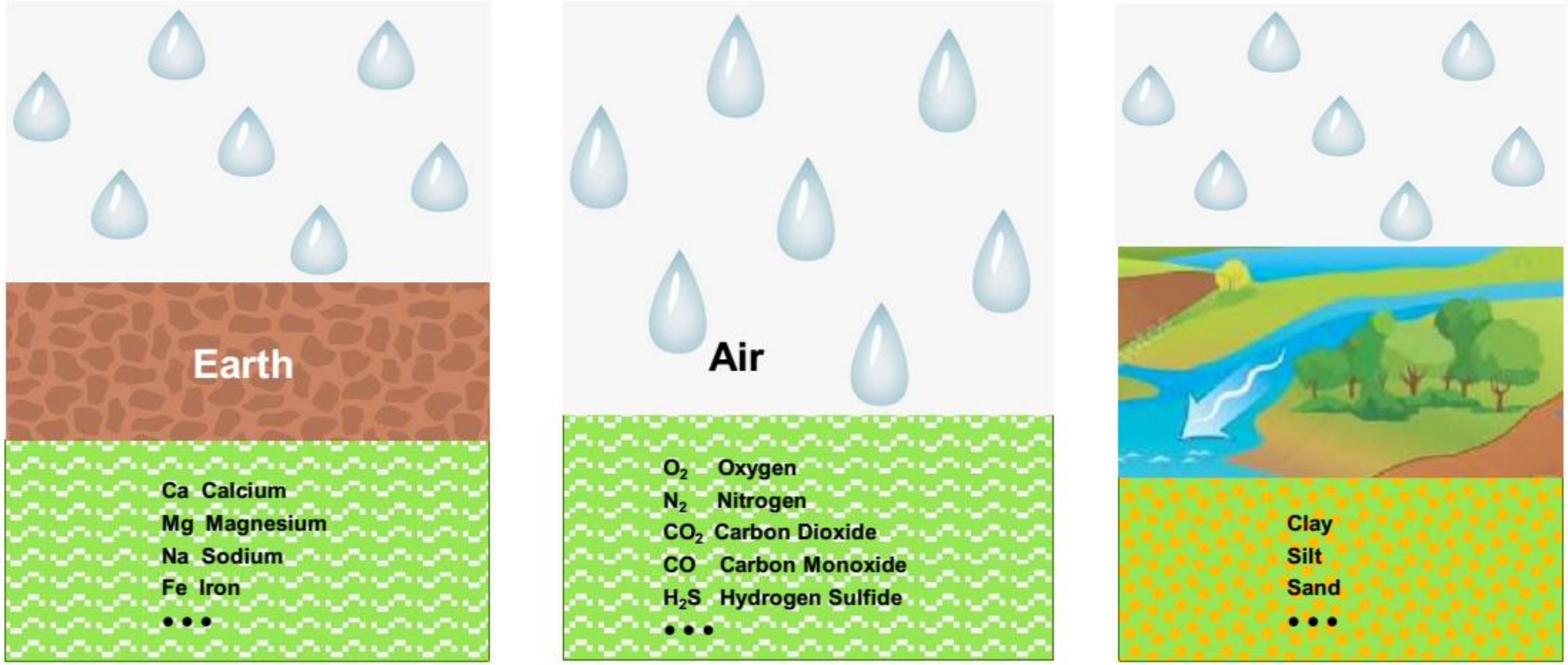

Dissolved Solids | Dissolved Gases | Suspended Solids

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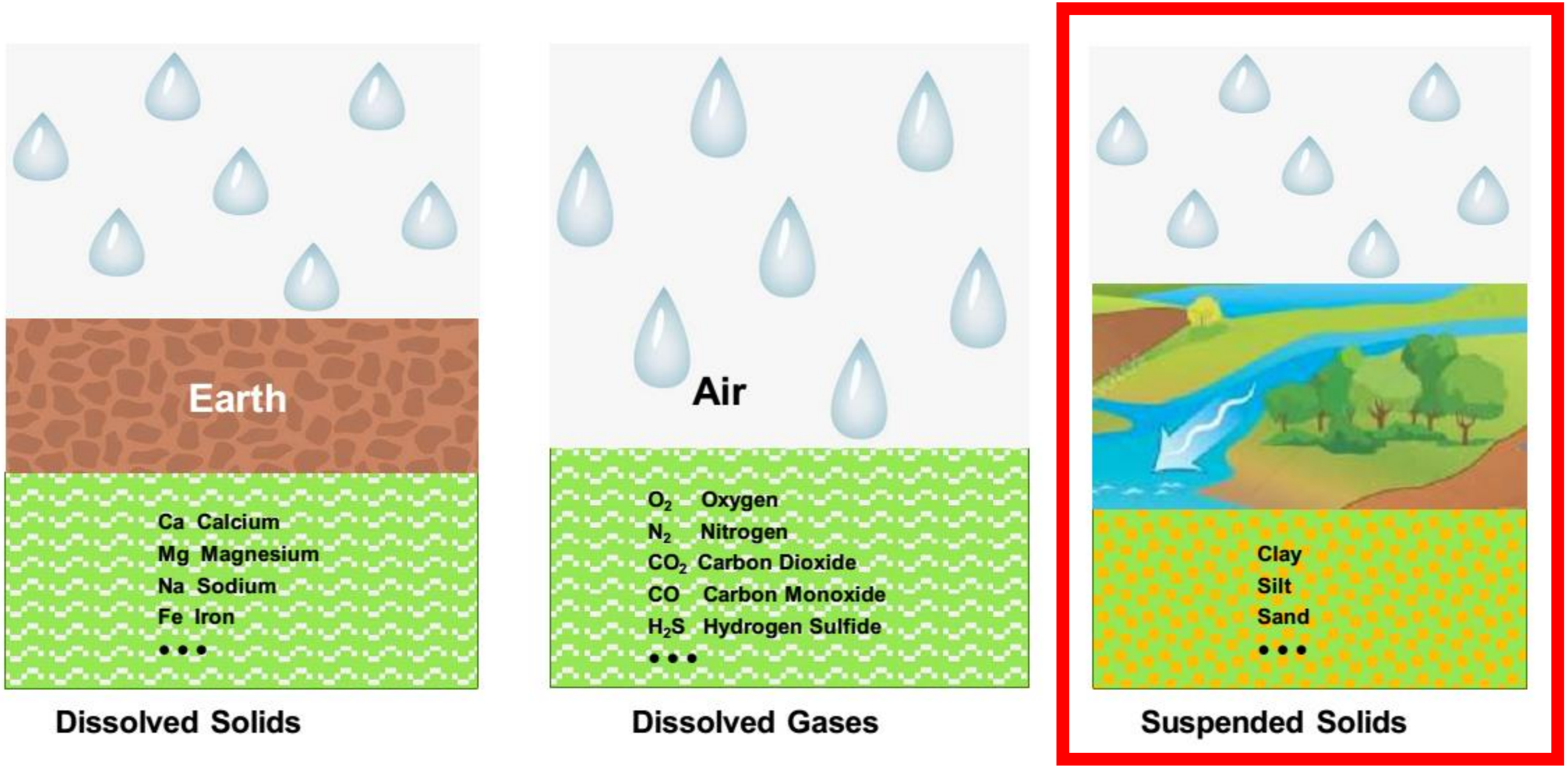
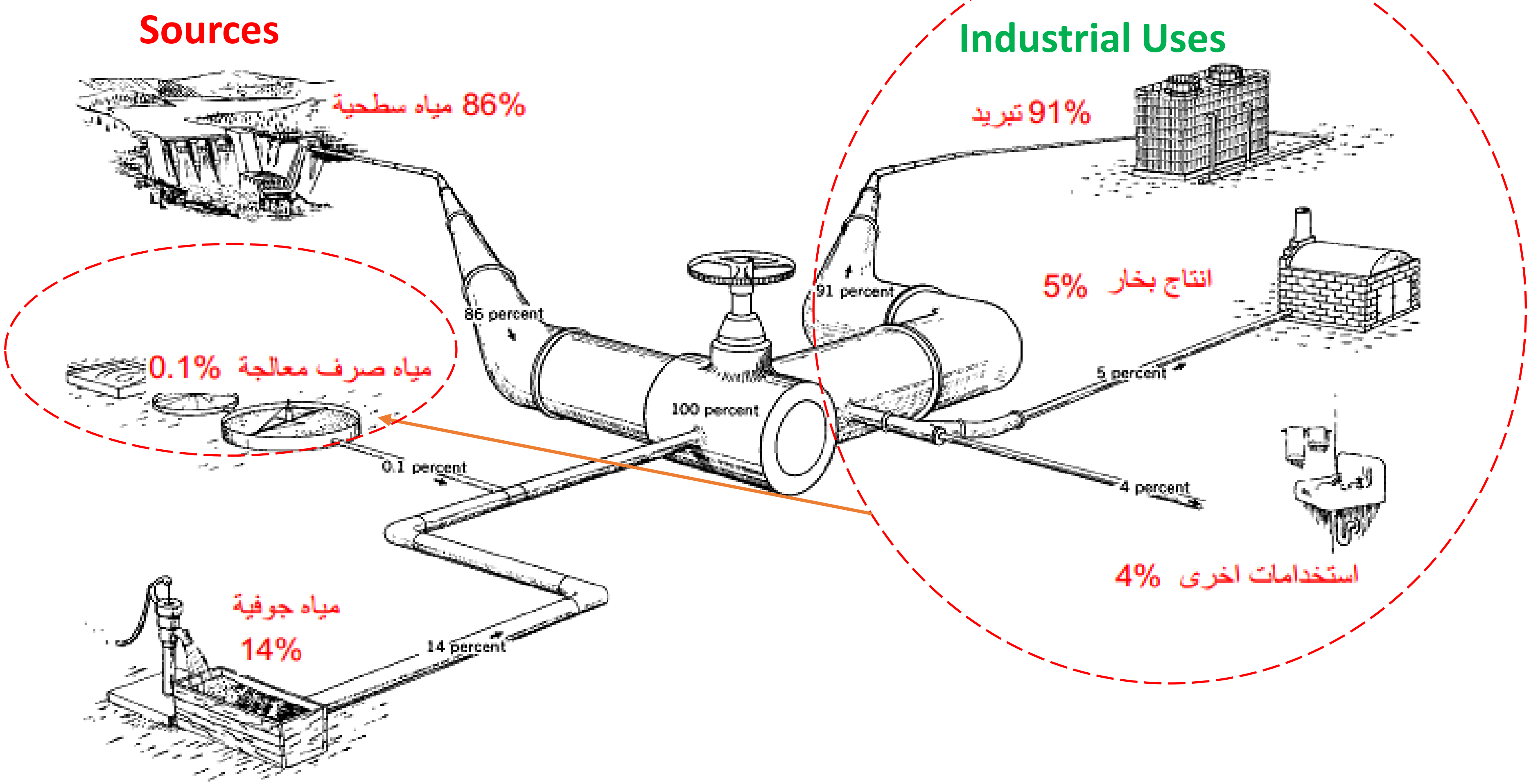
What is in Water



Suspended Solids

زمن الترسيب في المياه(عمق 1 متر)	نوع المادة الصلبة
1 ثانية	الطوب والزلط
10 ثواني	الرمل الخشن
100 ثانية	الرمل الناعم
ساعة ونصف	التربة الصفراء
اربعة ايام!!!!!!!!	البكتريا
سنة ونصف!!!!!!!	الطمي الاسود
300 سنة !!!!!!!!!!	الغرويات

Industry Water Sources and Uses



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Boiler Feed Water Specifications

End User Requirements Determines Specifications

Depending on:

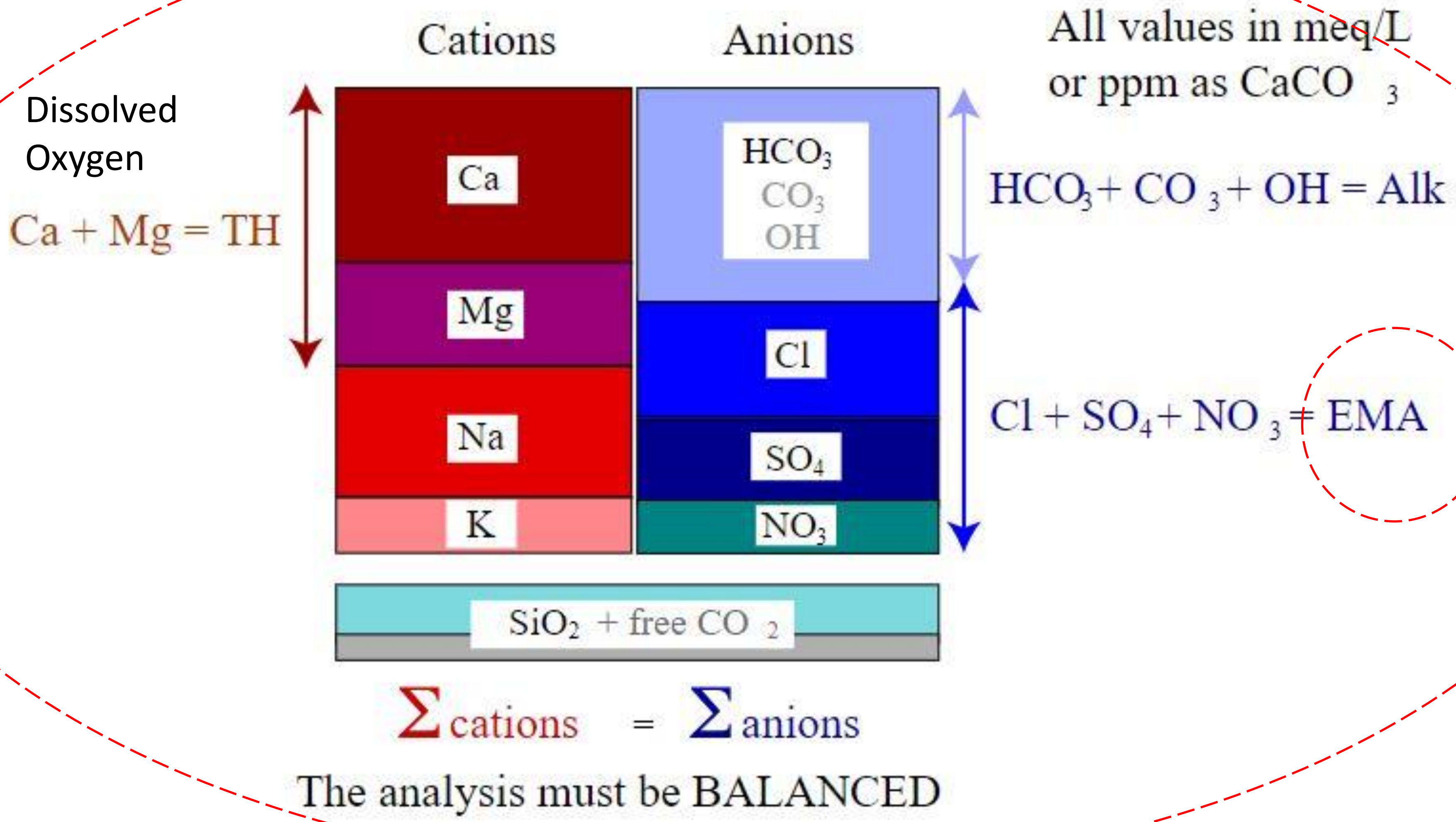
- **level of impurities present in raw water,**
- **FW quality required for the End User** and
- **Operating Conditions**,

a suitable water treatment process is selected.

- ➢ Each Specification has reference with dedicated **Standard**
- ➢ Each Standard can dramatically change the way of how to treat Water!
- ➢ Boiler Feed Water British Standard(EN 12952-12:2003)
- ➢ Hydro processing Wash Water(API-rb-932-b)

General Feed Water Characteristics

Dissolved Oxygen



Types of Water used in a power or process plant:

- *Raw water*. Water received at the premises of the users regardless of any previous treatment. The sources may be a river, lake, well, mine water, and so on.
- *Softened water*. Water whose hardness has been removed substantially.
- Decationized Water: Water whose all Cations Removed
- Degassed Water: Water Without Co2

Types of Water used in a power or process plant:

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- *Raw water*. Water received at the premises of the users regardless of any previous treatment. The sources may be a river, lake, well, mine water, and so on.
- *Softened water*. Water whose hardness has been removed substantially.
- *Condensate*. Condensed steam returned from a power or process plant without mixing with any other water.
- *Demineralized water*. Water nearly freed from total ionized dissolved solids by passing through ion exchange materials.
- *Feed water*. Water passing through the feed pumps or ejectors containing any mixture of the above-mentioned waters to process units(treatment-boiler-…) .
- *Boiler water*. Water in the boiler vessels with steaming in progress.
- *Makeup water*. Water added to the system to compensate for losses.

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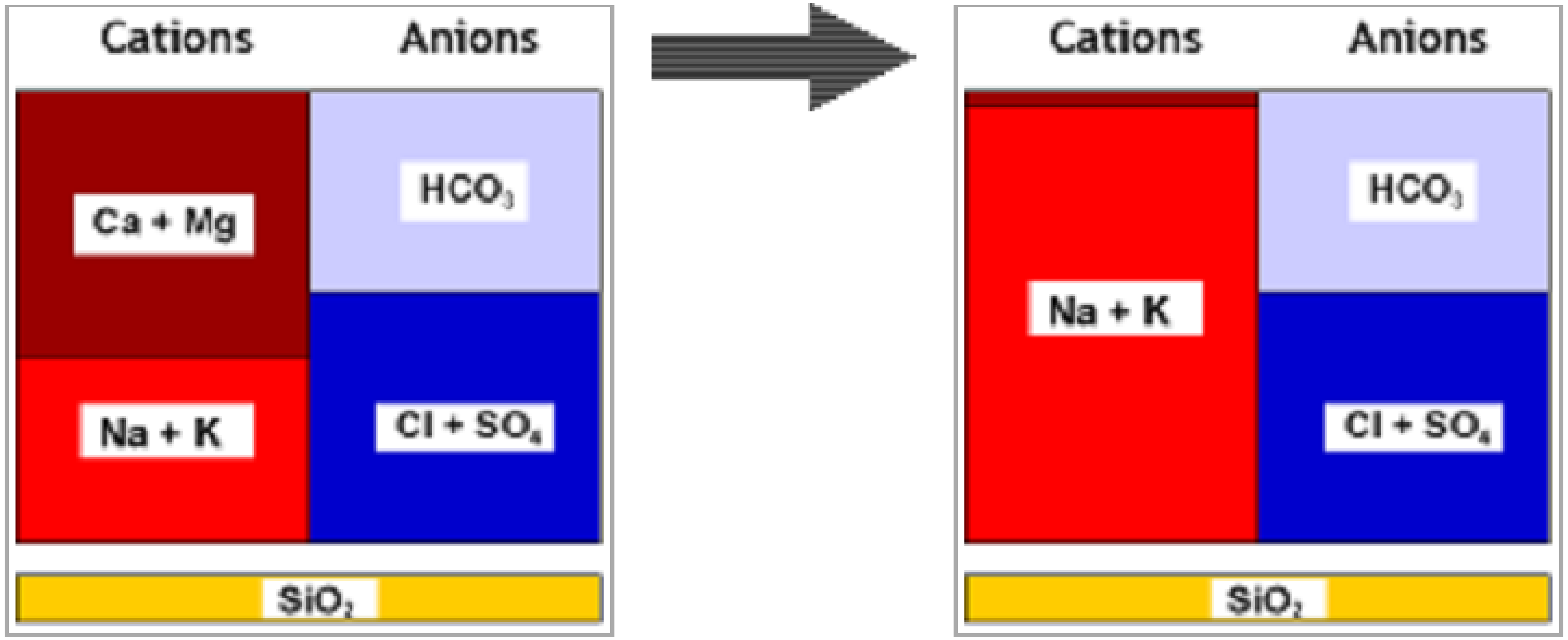
Soft Water



Raw water

Softened water

Soft Water

- The water salinity is unchanged, only the hardness has been replaced by sodium.
- A small residual hardness is still there, its value depending on regeneration conditions.
- Water for low pressure boilers

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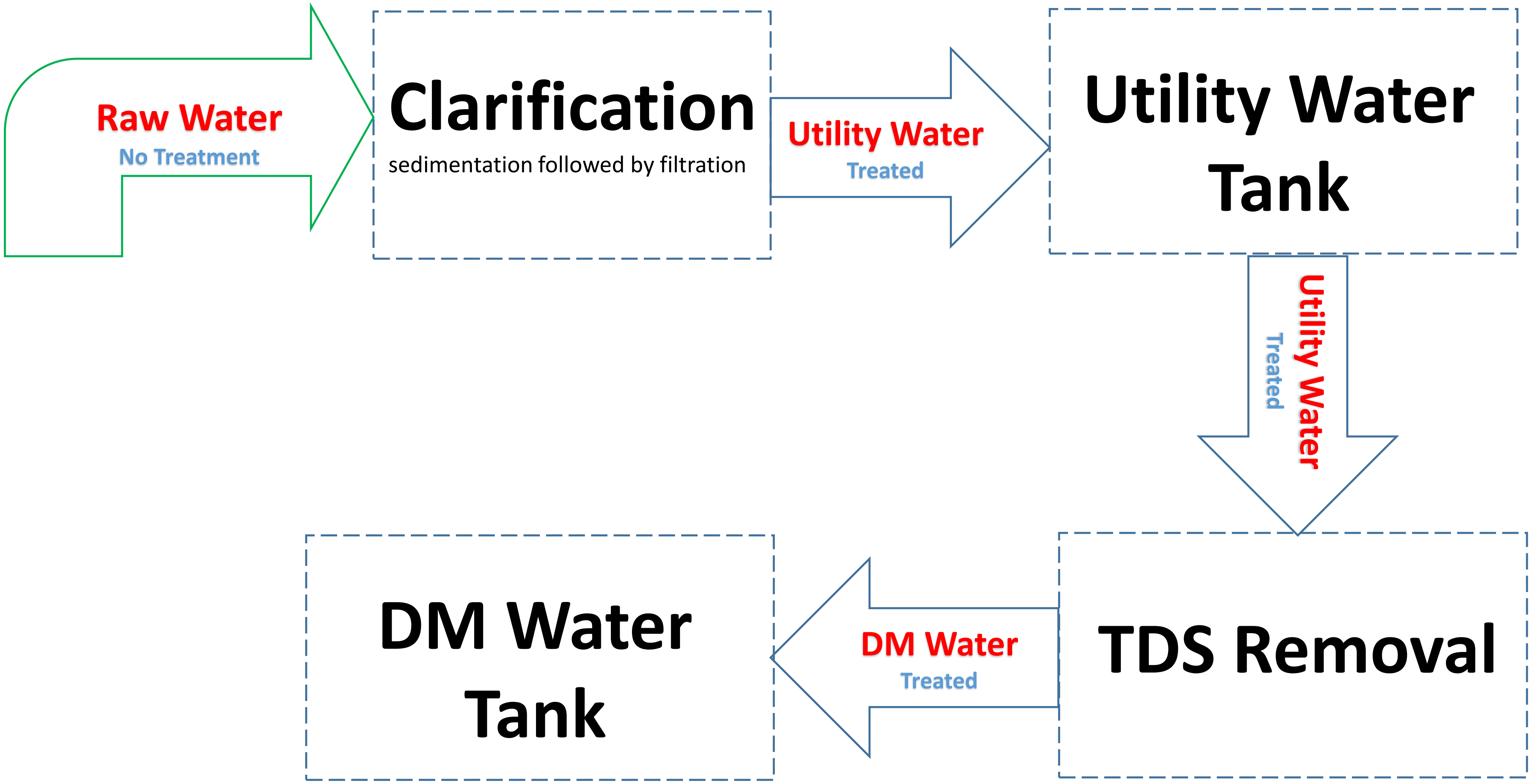

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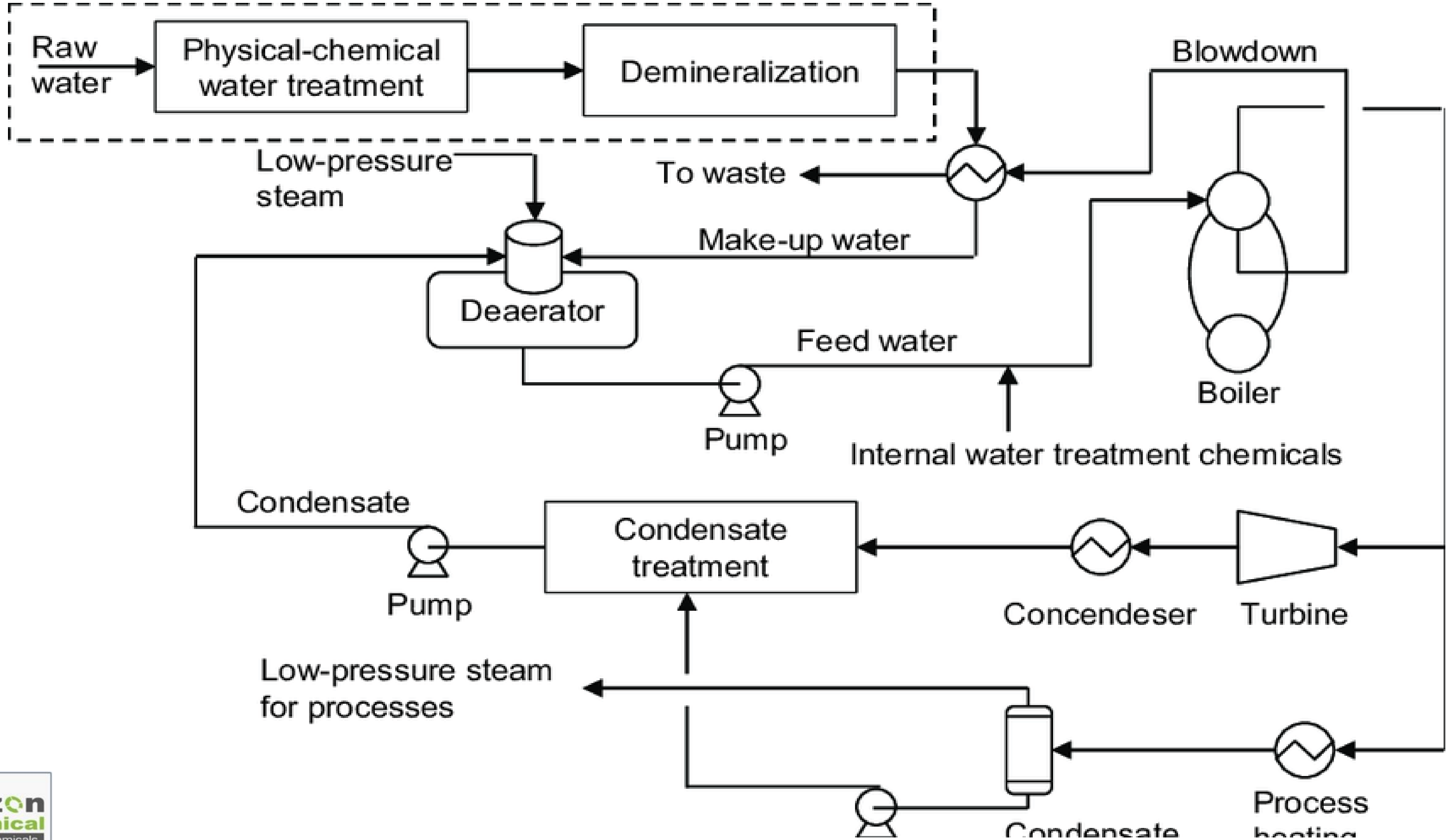
Typical Steam Generation System Layout

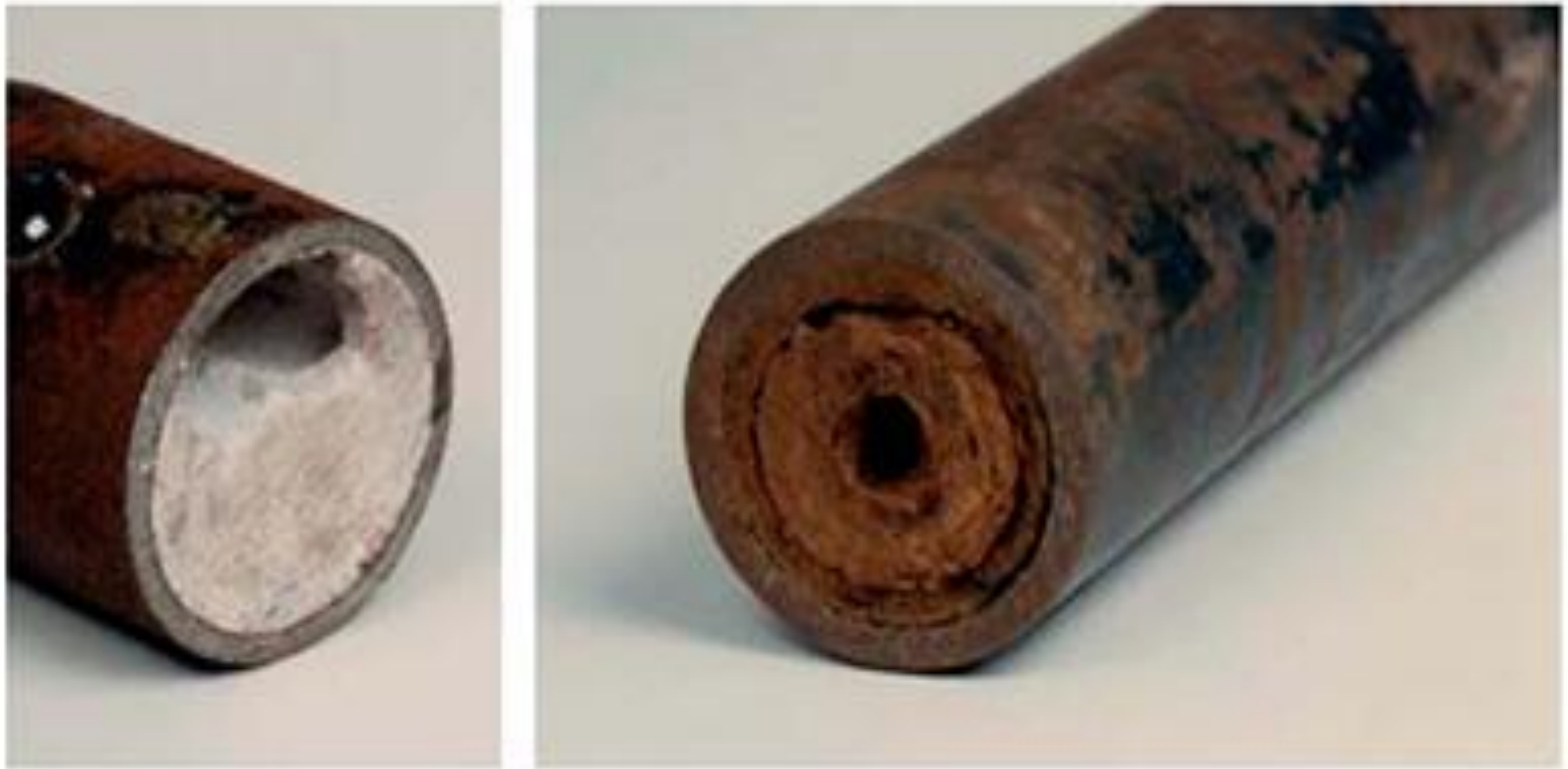


Effects of Water on Boilers

Water, although adequately treated, harms the boilers in three ways, unless it is *conditioned* suitably:

1. ***Scaling***
2. ***Corrosion***
3. ***Carryover***
4. ***Foaming***

Scale Formation(Precipitation)



Boiler scale on water side

SCALE CRISIS

- scale is caused by impurities being precipitated out of the water directly on heat transfer surfaces or by suspended matter in water settling out on the metal and becoming hard and adherent.
- Evaporation in a boiler causes impurities to concentrate. This interferes with heat transfers and may cause hot spots.
- Leading to local overheating.

SCALE CRISIS

- Scaling is mainly due to the presence of **calcium and magnesium** salts (***carbonates or sulphates***), which are less soluble hot than cold, or to the presence of too high concentration of silica in relation to the alkalinity of the water in the boiler.

SCALE CRISIS

- scaling causes progressive **lowering of the boiler efficiency** by heat retardation, acting as an insulator.
- Eventually, scale built-up will cause the **tube to overheat and rupture!**
- Boiler deposits can also cause **corrosive attack underneath the Scale!**

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SCALE CRISIS

- Scaling is mainly due to the presence of **calcium** and **magnesium** salts (carbonates or sulphates), which are less soluble hot than cold, or to the presence of too high concentration of silica in relation to the alkalinity of the water in the boiler.

MINERAL SCALE

Commonly encountered cooling water scales:

Water Hardness Ca & Mg

Calcium Carbonate
Calcium Phosphate
Iron Phosphate
Iron Oxides
Magnesium Silicate

Calcium Sulfate
Zinc Phosphate
Aluminum Phosphate
Calcium Fluoride

Factors Affecting Scale Formation

- Mineral Concentration
- Water Temperature
- Water pH
- Suspended Solids
- Water Flow Velocity

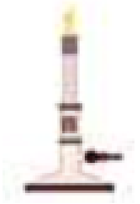
As water utilization increases through recycle & reuse, the potential for mineral scale rise exponentially

SCALES FORMATION

CALCIUM CARBONATE MOST COMMON COOLING SYSTEM SCALE

Calcium Carbonate : $CaCO_3$ Forms when saturation is exceeded

$$Ca + 2HCO_3 \xrightarrow{Heat} CaCO_3 \downarrow + CO_2 \uparrow + H_2O$$



Scale Formation Drivers

- ↑ Mineral Concentration [Ca , Mg , CO_3 , PO_4 • • •]
- ↑ Water Temperature
- ↑ Water pH [HCO_3 , CO_3]
- ↑ Suspended Solids
- ↓ Water Flow Velocity

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Cycles of Concentration

- “Cycles of concentration” is one of the most important concepts in boiler and cooling water treatment. It measures the degree to which the solid impurities in the makeup water are concentrated in the recirculating water of an evaporative system. The higher this ratio, the more the impurities in the makeup water are being concentrated in the system water. It can be estimated by dividing the conductivity of the system water by the conductivity of the makeup, or by dividing the chloride of the system water by the chloride of the makeup.

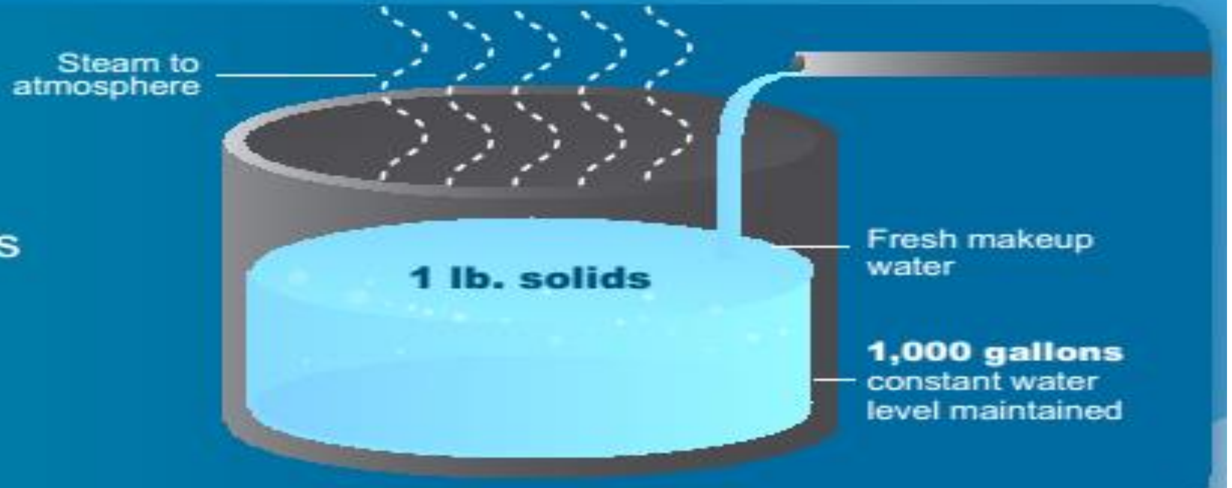
Cycles of Concentration

EXAMPLE CONDITIONS

- 1,000 gallon tank of water
- Fresh makeup water contains 1 pound of dissolved-solids impurities per 1,000 gallons
- 1,000 gallon water level maintained in each tank after evaporative losses by using fresh makeup water

1 CYCLE

- 1,000-gallons
- 1 pound dissolved solids



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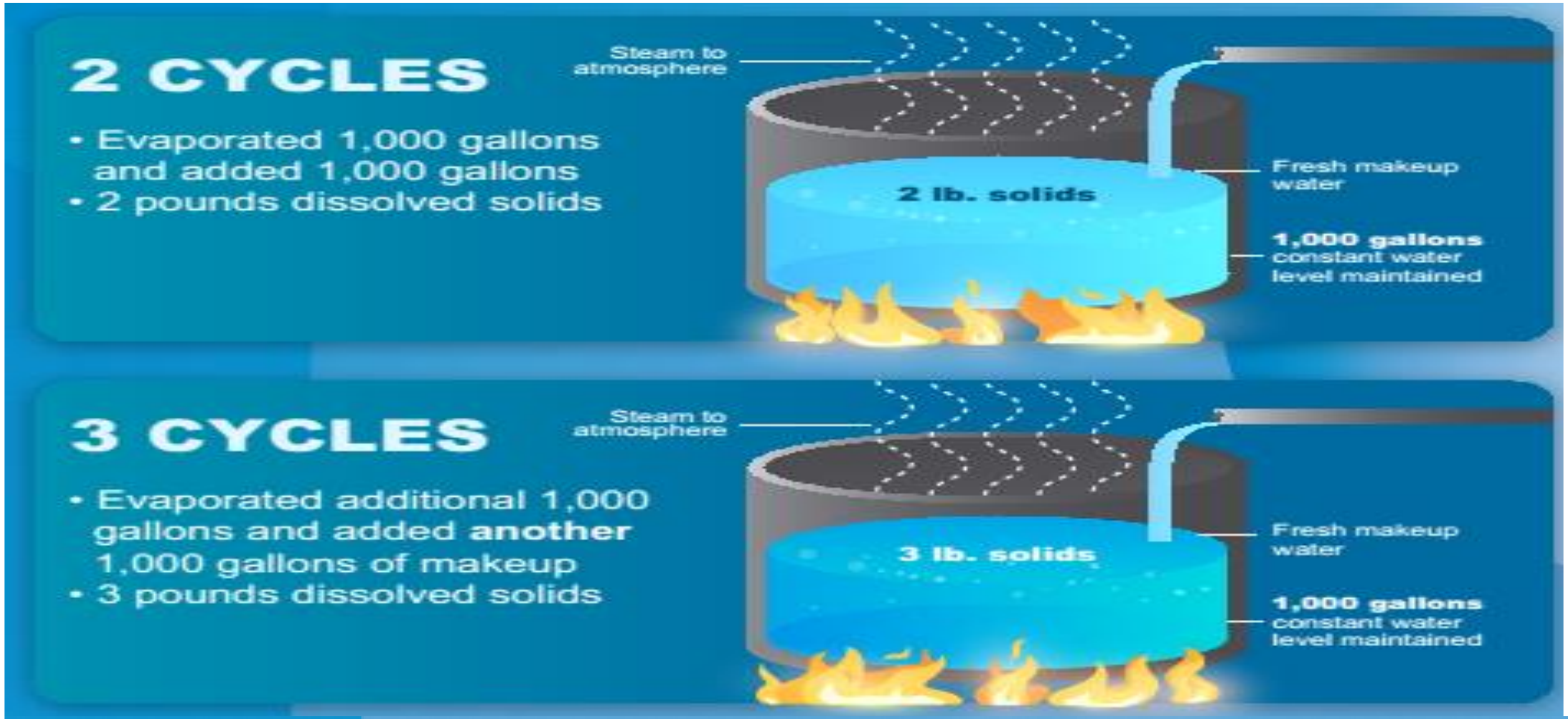
Cycles of Concentration



$$\text{Cycles} = \frac{\text{Conductivity}_{\text{System Water}}}{\text{Conductivity}_{\text{Makeup}}} = \frac{\text{Chloride}_{\text{System Water}}}{\text{Chloride}_{\text{Makeup}}} = \frac{\text{Silica}_{\text{System Water}}}{\text{Silica}_{\text{Makeup}}}$$

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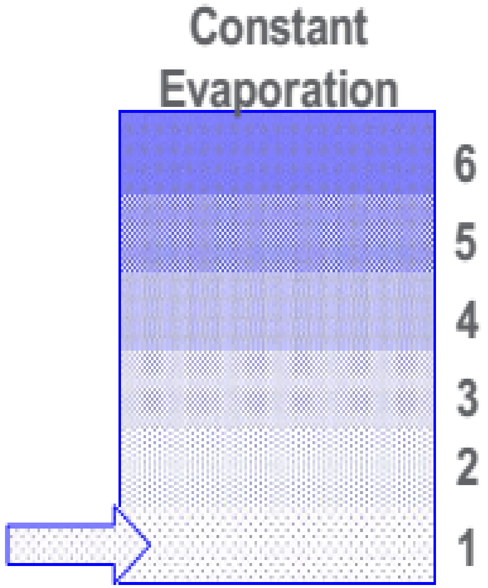
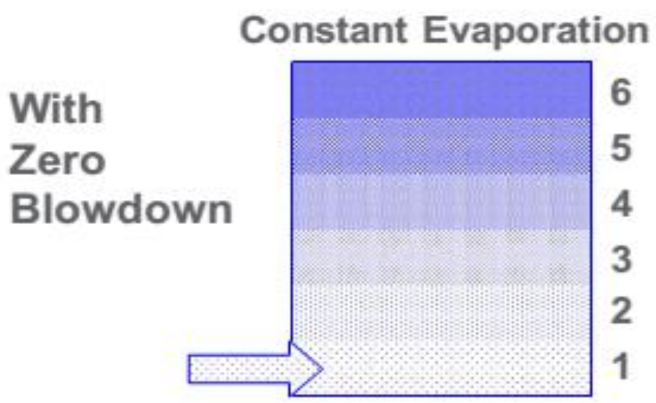
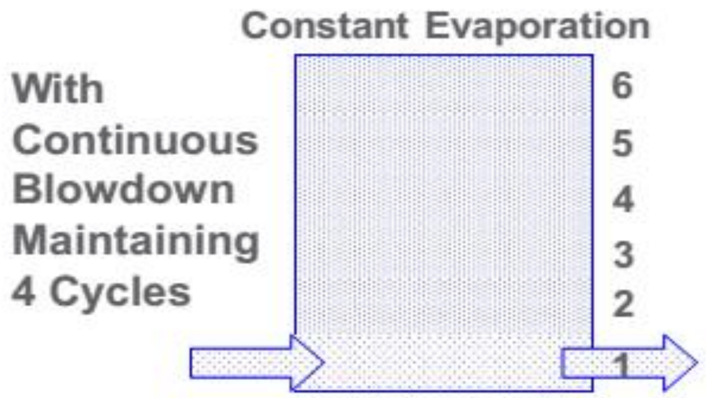
CONCENTRATION OF DISSOLVED SOLIDS

- Only pure water can evaporate
- No dissolved solids leave the liquid water
- If there are no other water losses from the system, the evaporation process causes an increase in the concentration of dissolved solids in the recirculating cooling water.
- Mineral scale will form if the dissolved solids concentration in the cooling water becomes too high (**Supersaturation)**



Impact of Blowdown to fight Scale





Blowdown:

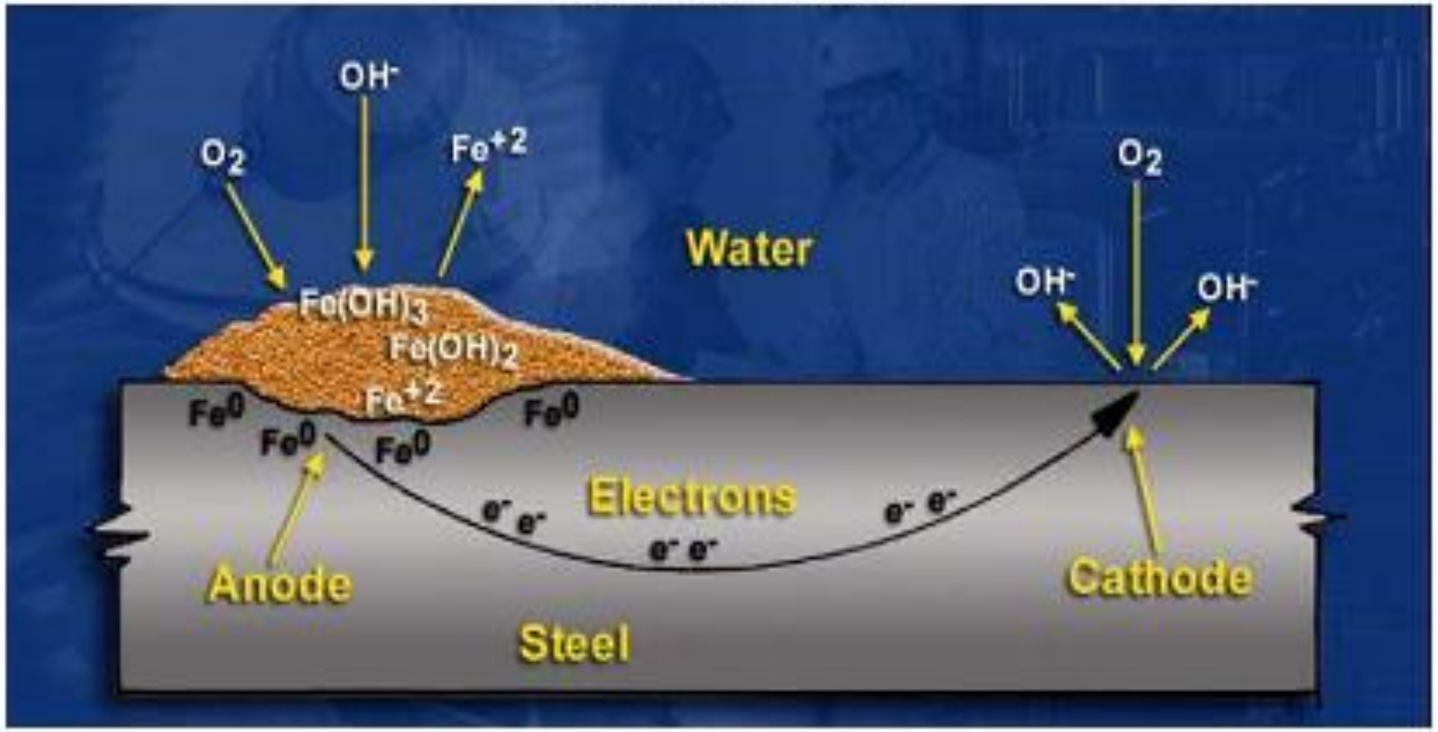
- Deliberate discharge of water to prevent the dissolved solids from getting to high

Corrosion

SIMPLIFIED CORROSION CELL

CORROSION

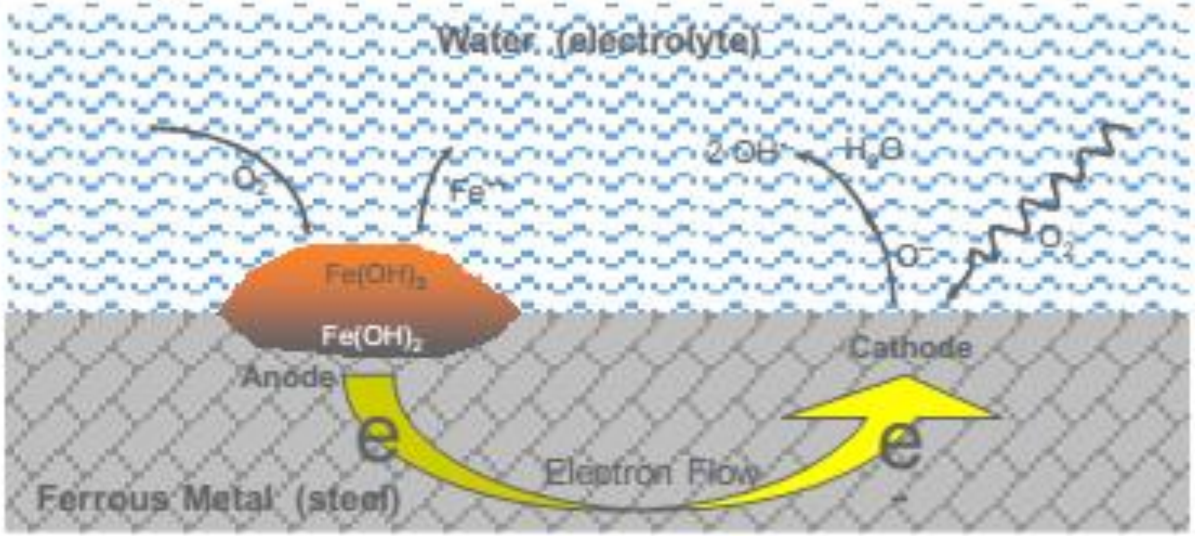
CORROSION is an electrochemical process by which metals are reverted back to their natural "oxidized" state.



Corrosion

Definition:

Corrosion is an electrochemical process by which a metal return to its more stable state (oxide), process requires anode, cathode and electrolyte such as water.



Anodic Reactions

Chemical Oxidation

$$Fe^{0} \longrightarrow Fe^{++} + 2e^{-}$$

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

$$2\,Fe(OH)_2 + H_2O + ½\,O_2 \longrightarrow 2\,Fe(OH)_3$$

Cathodic Reaction

Chemical Reduction

In neutral or alkaline water

$$H_2O + ½\,O_2 + 2e^{-} \longrightarrow 2\,OH^{-}$$

CORROSION

Corrosion Types

General or Uniform	Crevice/Underdeposit
Pitting	Galvanic
Velocity Effect	Dealloying
Stress Corrosion Cracking	Intergranular

General Or Uniform: relatively easy to measure, predict and control.

Crevice/Under deposit: localized form results from stagnant solutions located in crevices, joints and lap joints. Generally very aggressive.

Pitting corrosion: creates cavities or holes in the metal being corroded, difficult to detect or predict. (corrosion product covering the pits)

Galvanic corrosion; results when two dissimilar metals are connected and expose to a water environment.

Velocity Effect: erosion or corrosion due to water flow.

- High velocity flow quickly erode any protective film applied to he pipe.
- Low velocity flow allow sediment to settle on the pipe, localized corrosion

Stress corrosion Cracking: Cracking of the alloy brought by the combined influence of tensile stress and corrosion.
Its common in the passive alloys such as SS where its induced by aggressive chloride ions.

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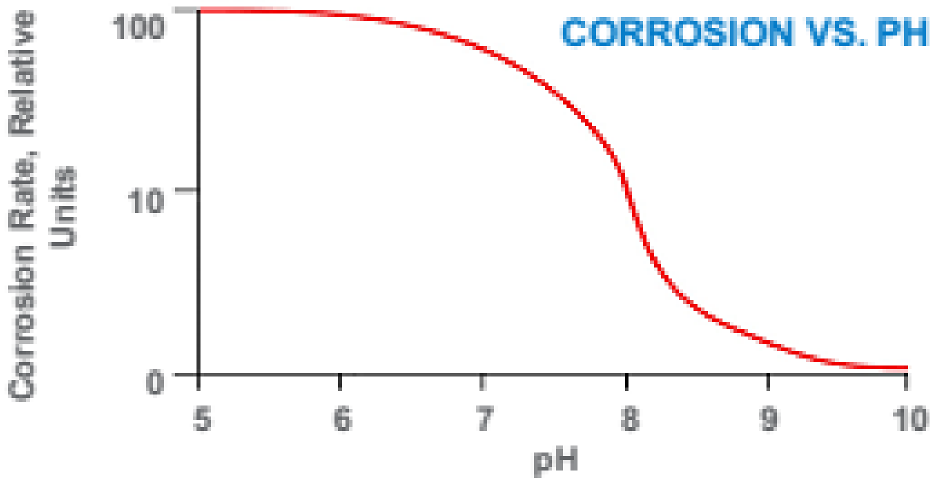
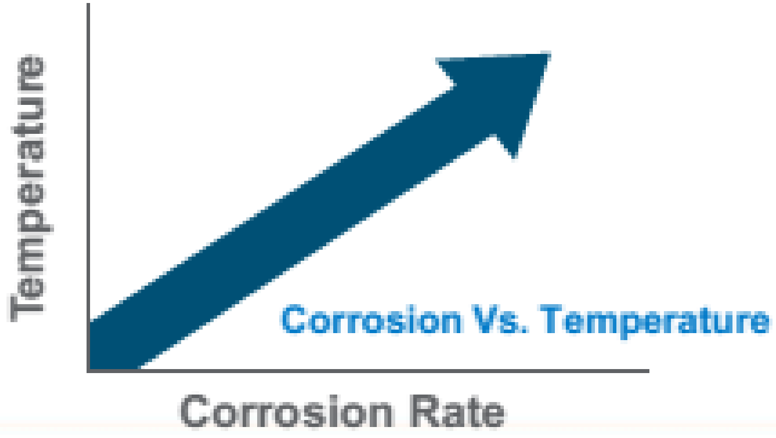
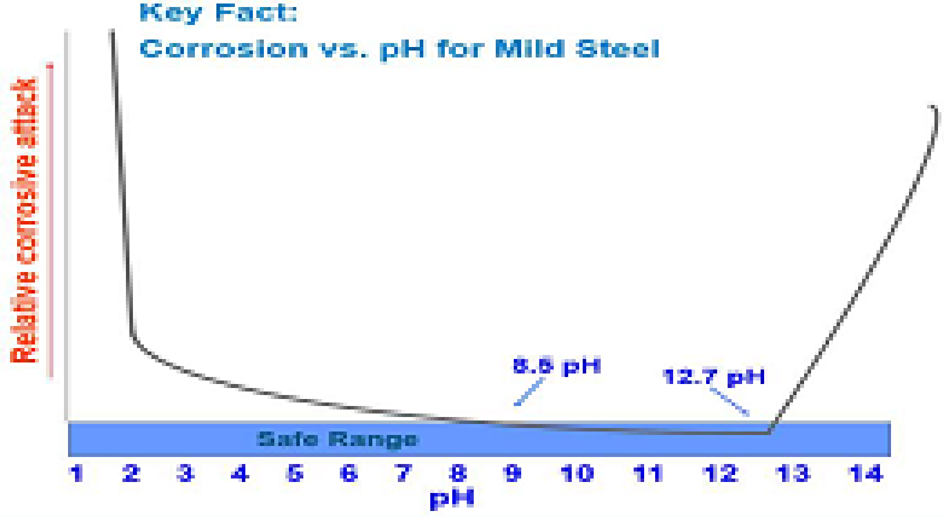
Factors Influencing Corrosion

- pH , acidity or alkalinity
- Oxygen and dissolved gases
- Dissolved solids (ionic strength) (anions Cl & SO_4)
- Biological activity (sessile, acidic end products, hydrogen sulfide)
- Water Velocity
- Suspended solids (abrasive action and settling)
- Other • • •







FACTORS INFLUENCING CORROSION

Variables

pH/Alkalinity

Conductivity

pH/Alkalinity
pH and alkaline levels are important variables in whether the environment is conducive to corrosive attack. Low pH and alkaline levels contribute to an increased likelihood that corrosion will occur. High pH and high alkalinity levels contribute to increased deposit formation under which underdeposit corrosion can occur.

Conductivity
This refers to how well water will conduct electrical current. The corrosion process is an electro chemical process that requires a current flowing from the anode to the cathode. Dissolved ionic solids in water serve as an electrolyte to conduct this current.

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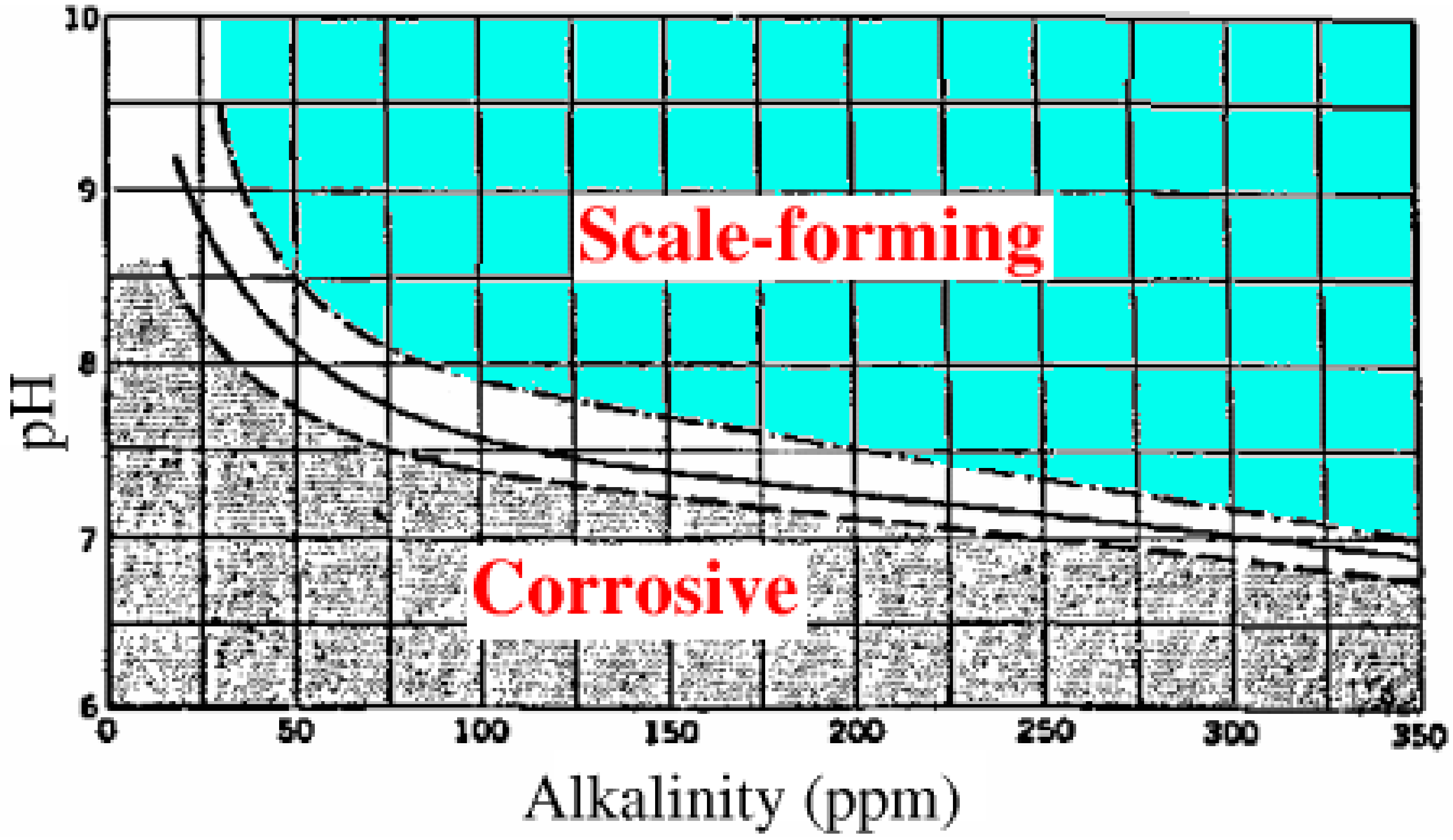
PH,Alkalinity,Scale,Corrosion



CO2 Vs. pH Vs. Alkalinity

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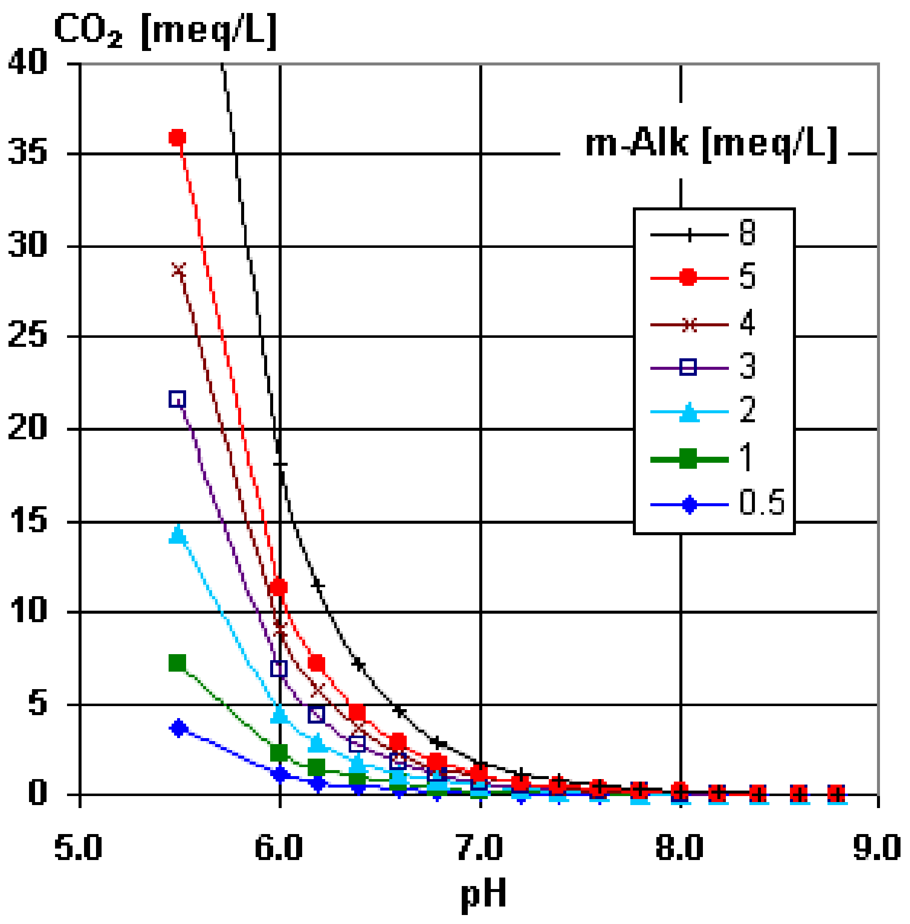

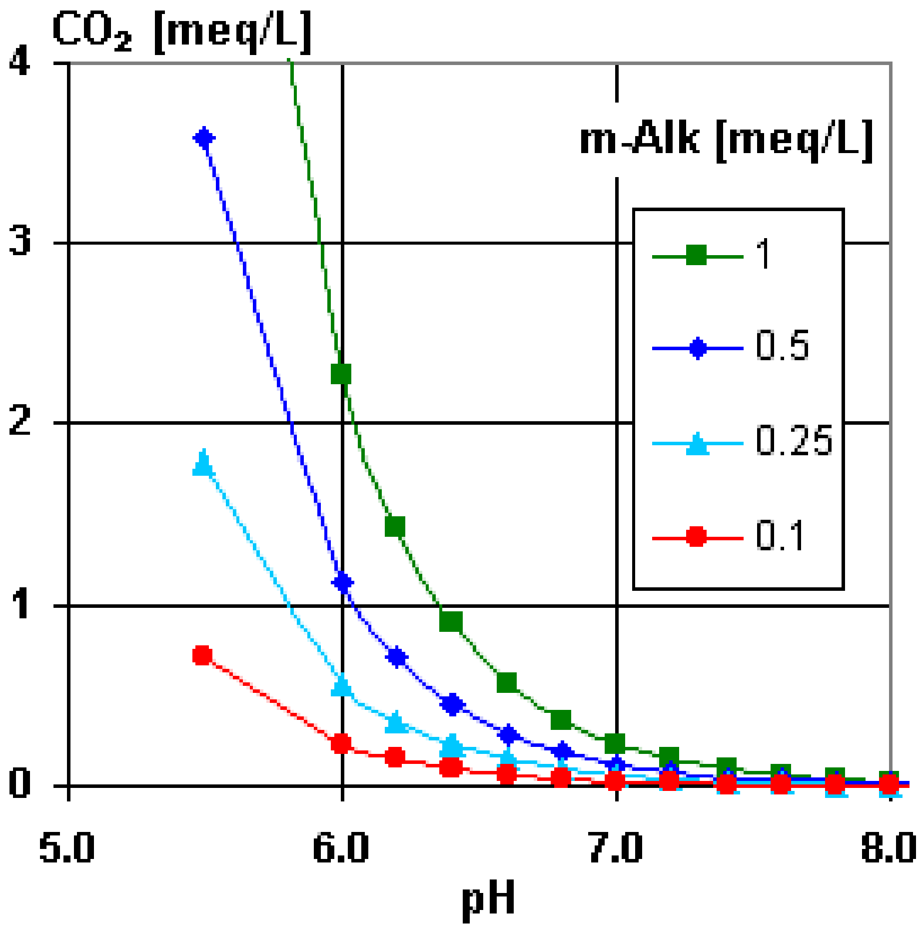

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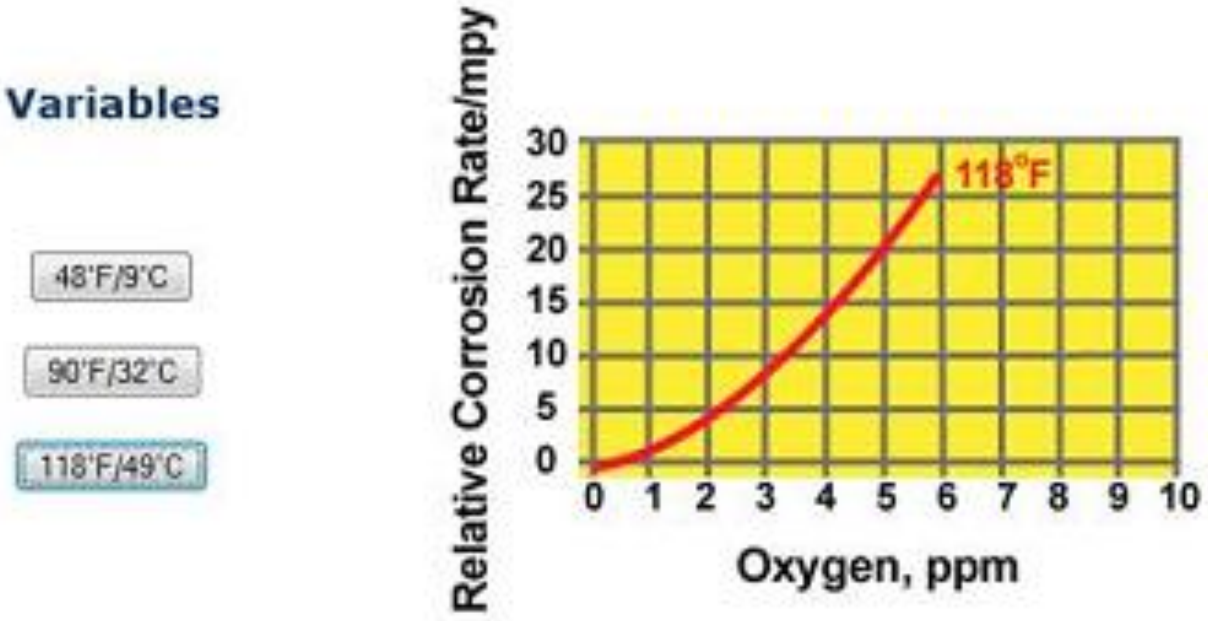
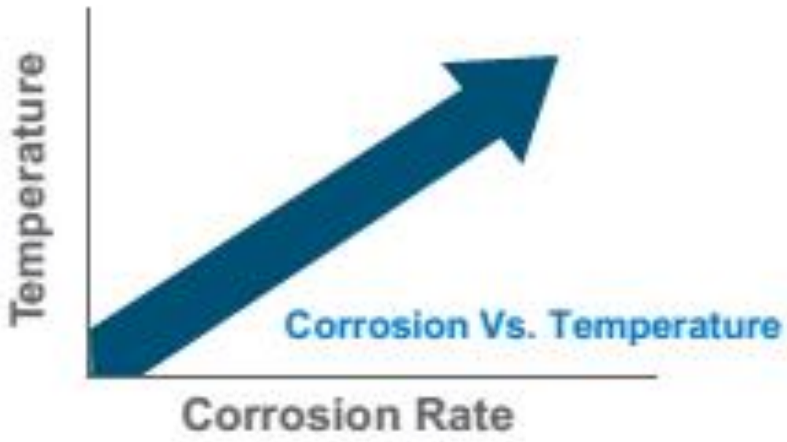
CORROSION RATE AND TEMPERATURE





Increases in temperature and oxygen will usually increase the rate of most corrosion reactions. As a rule, each 18 degrees Fahrenheit increase in temperature doubles the rate of most chemical reactions. As the temperature increases, the cathodic reaction proceeds faster, and the oxygen diffusion rate improves. Click the button to view the results of this process.

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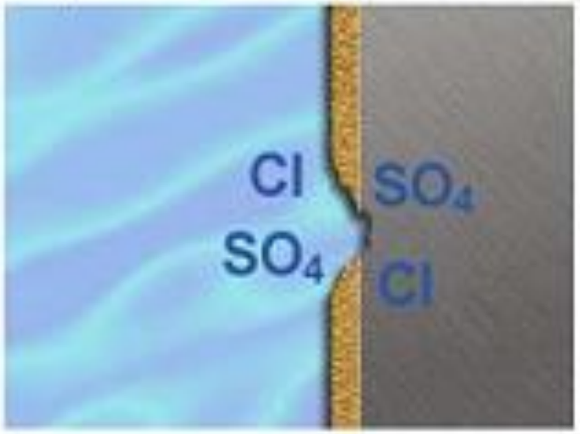
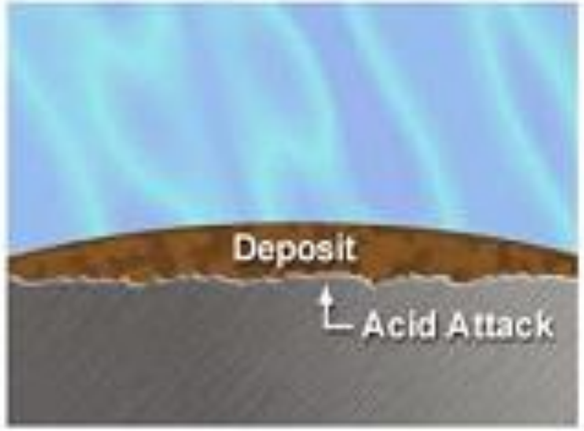
DISSOLVED SOLIDS AND CORROSION

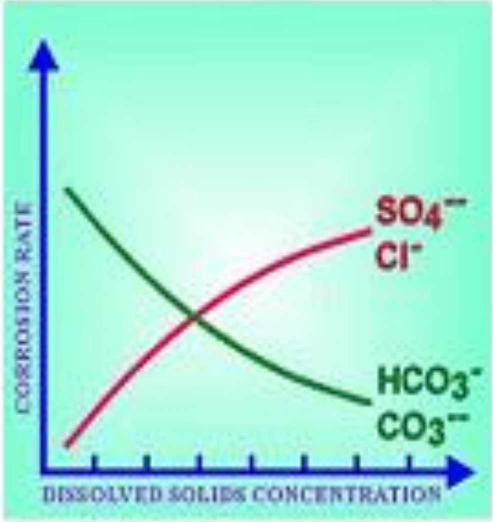
Dissolved Solids

Aggressive chloride and sulfate ions can destroy the protective oxide layer on the metal surface.



Ions can concentrate under deposits to form localized corrosion.





Dissolved solids other than alkalinity influence corrosion based on the following factors: aggressive chloride and sulfate ions can destroy the protective oxide layer on the metal surface; the greater the concentration of aggressive ions, the faster corrosion occurs. Also ions can concentrate under deposits to form localized corrosion. The greater the concentration of aggressive ions present in solution, the more rapidly corrosion proceeds.

Main Processes Related to Water in Boilers

The following three processes must be understood by boiler engineers in proper detail,
along with the steam purity requirements of the downstream equipment and process:

1. **Deaeration**
2. **Water and steam conditioning**
3. **Carryover**

Boiler Water Conditioning

The purpose of Water conditioning is to:

1. Prevent scale formation

2. Remove traces of dissolved Oxygen

3. Corrosion Control

Deaeration and Oxygen Scavenging

- **Deaeration is the removal of dissolved gases, notably oxygen, from water.**
- **Dissolved gases cause many corrosion problems. Pitting caused by O2 (localized corrosion leading to pits) is particularly dangerous because the pits can lead to failure of parts under pressure**

Deaeration and Oxygen Scavenging

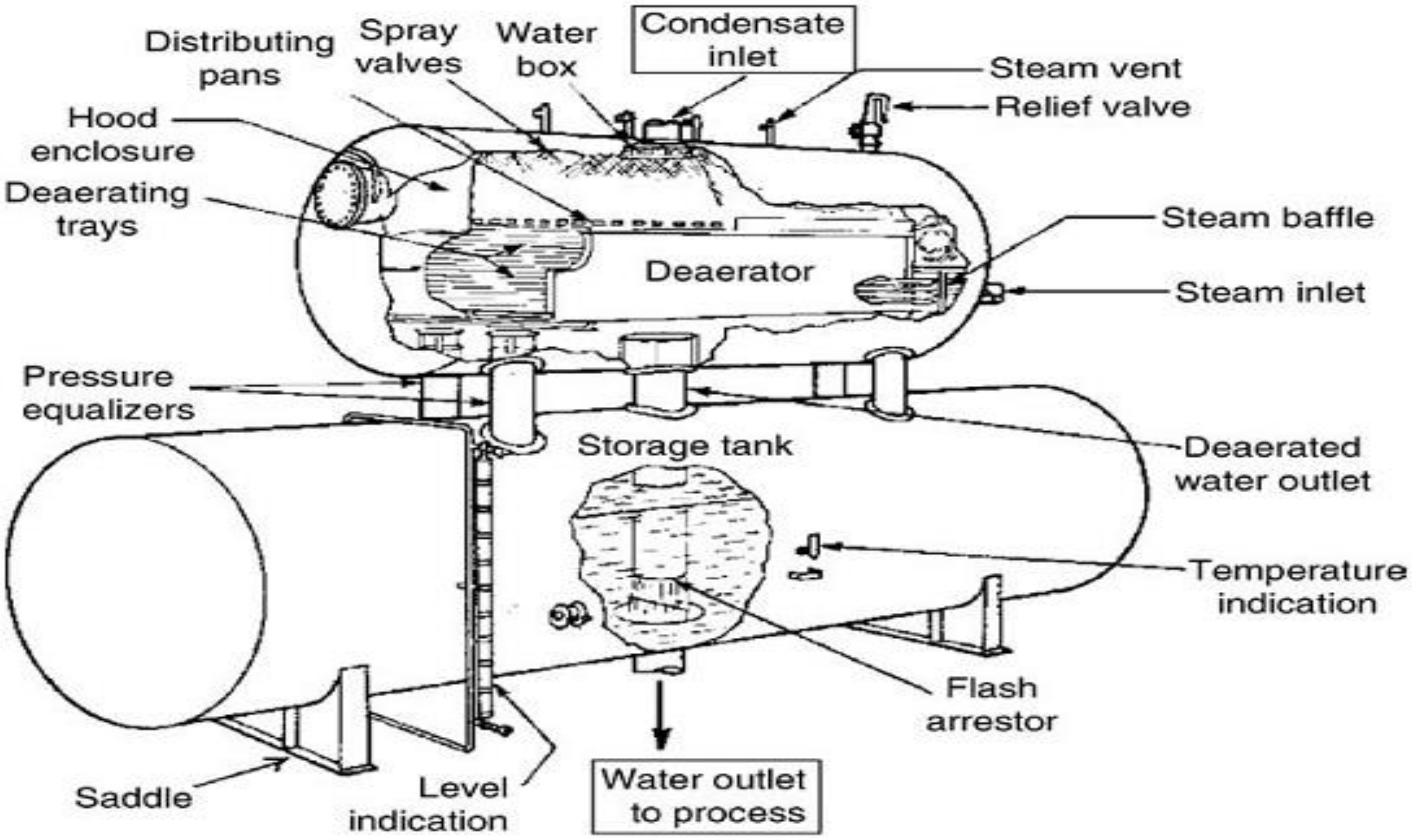
- Deaeration can be achieved by either mechanical separation or chemical reaction. The
practice in the industry is to adopt the following two consecutive steps:

1. Mechanical separation in hot condition, which is very effective, reliable, and cheap
2. Chemical reaction, which is called scavenging, to remove the traces.

Deaeration Principles

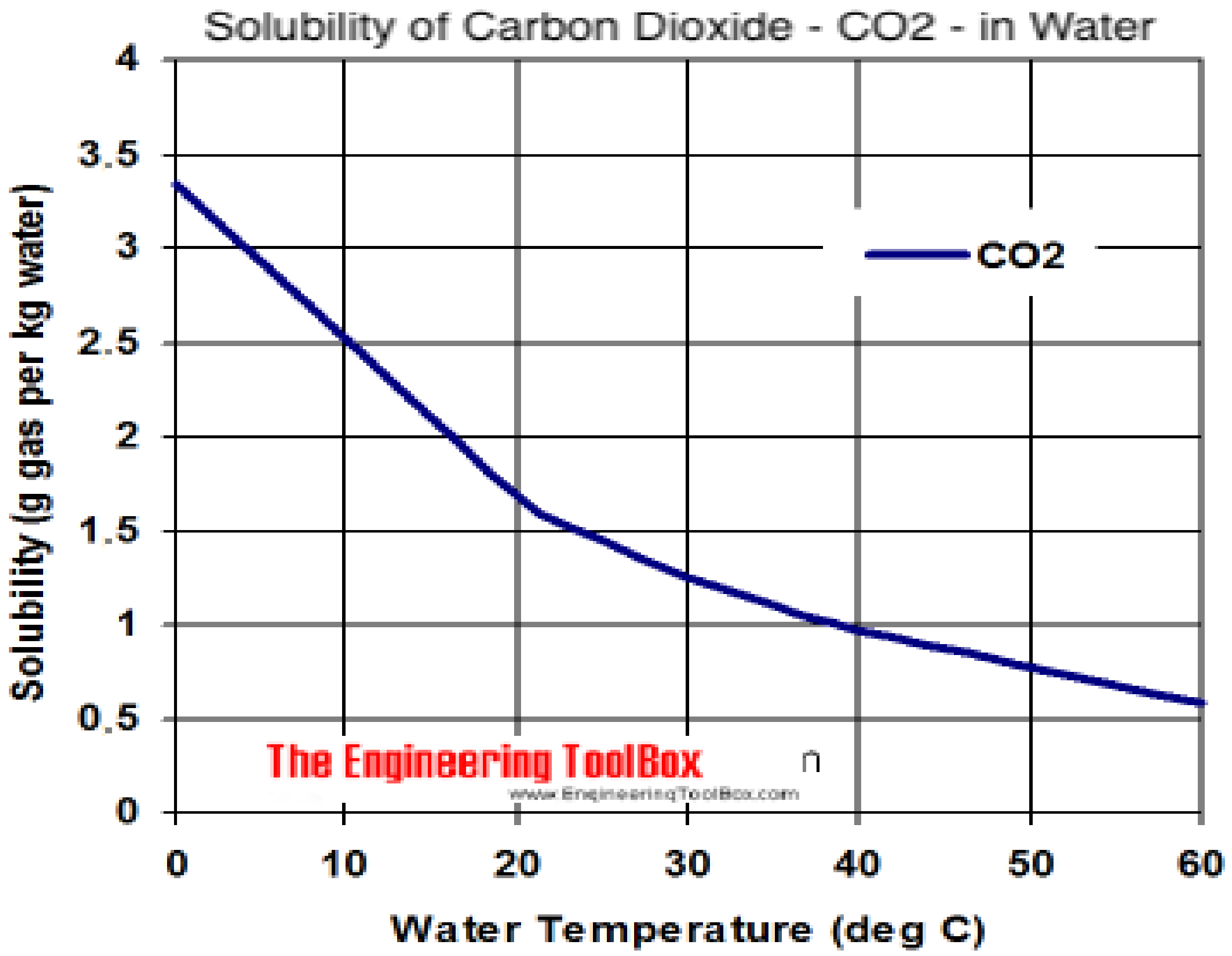
1. **Water droplets are reduced in size** so that the trapped gas has to travel smaller distance to reach the periphery.
2. **Increase water Temperature** lead to Surface tension and viscosity are lowered to make it easier for the gas to escape

Deaerator



Distributing pans
Spray valves
Water box
Condensate inlet
Steam vent
Relief valve
Hood enclosure
Deaerating trays
Steam baffle
Deaerator
Steam inlet
Pressure equalizers
Storage tank
Deaerated water outlet
Temperature indication
Flash arrestor
Saddle
Level indication
Water outlet to process

Carbon Dioxide Vs. Temperature



Oxygen Solubility Vs. Temperature

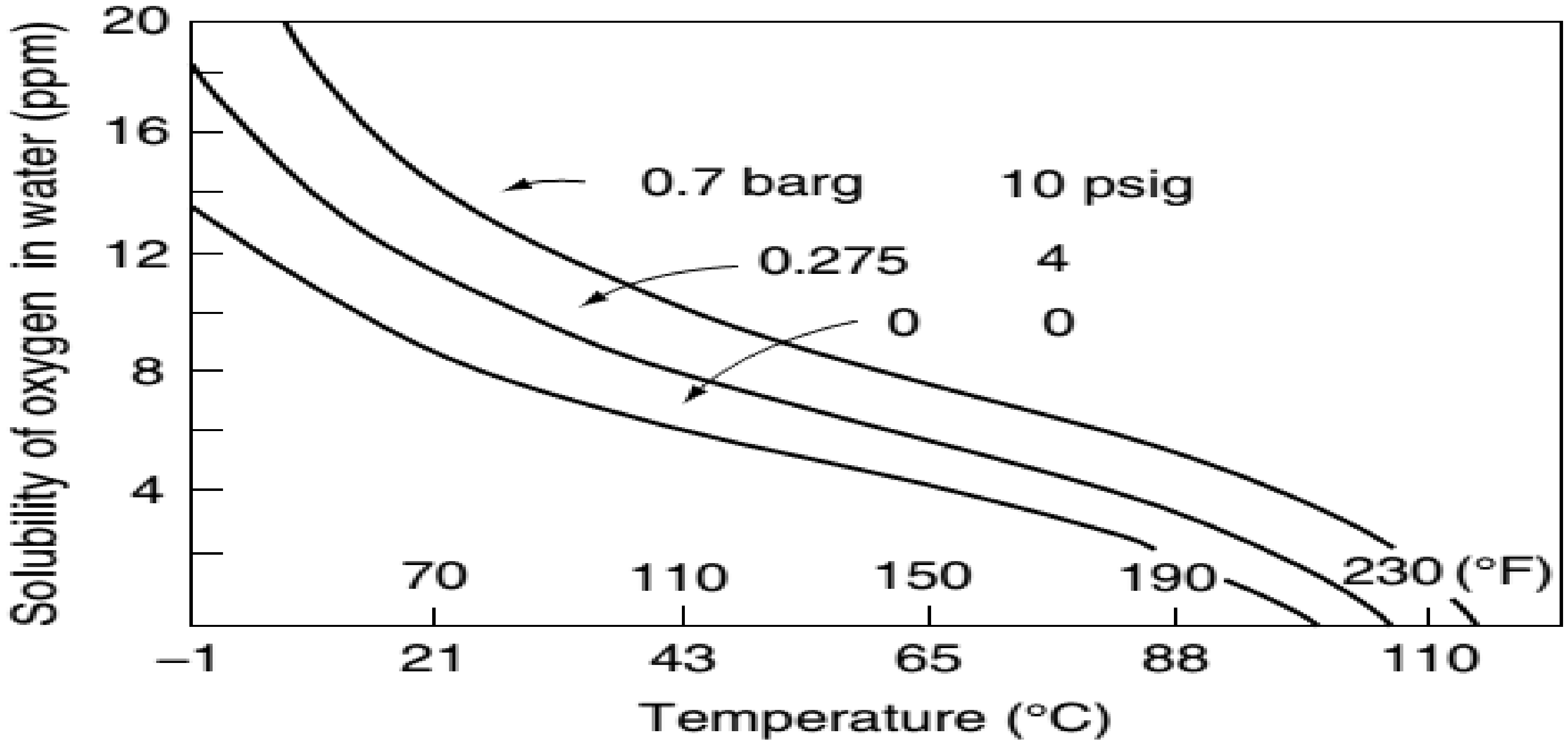


FIGURE 4.2
Solubility levels of oxygen in water.

Oxygen Scavenging

- Removal of last traces of oxygen is done by chemical scavengers such as sodium sulfite(Na_2SO_3) or hydrazine (N_2H_4).

  Sodium Sulfite (Na_2SO_3)

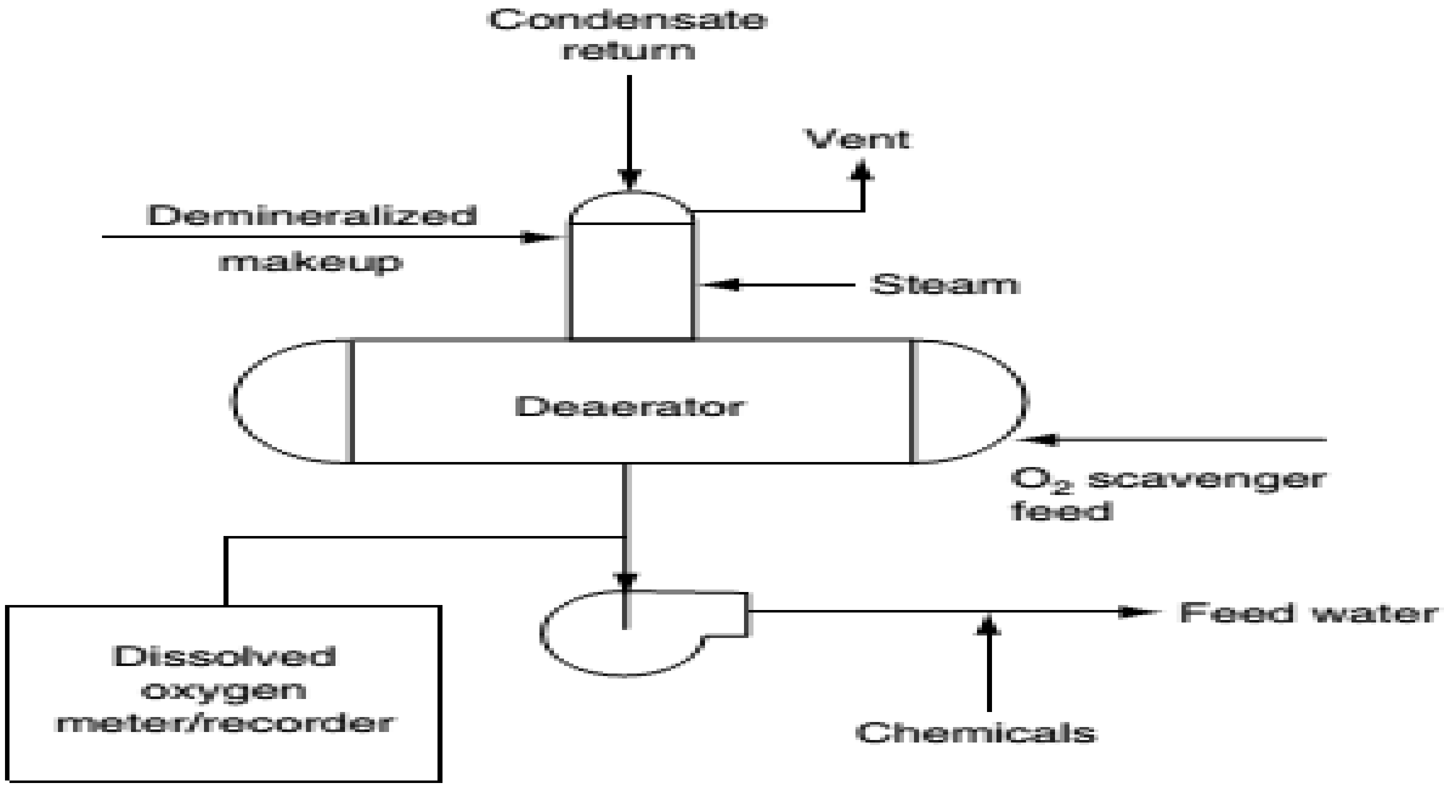
  For boilers operating at pressures <*70 bar*, catalyzed Na_2SO_3 is the most common O_2 scavenger due to its following features:
  1. Low cost
  2. Ease of handling
  3. Nonscaling properties

Oxygen Scavenging

- ***Hydrazine (N_2H_4)***

  For boilers operating at pressures >*70 bar*, hydrazine is preferred to sulfite as:
  1. Hydrazine adds no solids to the boiler water.
  2. Na_2SO_3 can decompose at higher pressures to form H_2S and SO_2 that can cause corrosion of return condensate system.

Deaerator


Condensate return
Vent
Demineralized makeup
Steam
Deaerator
O_2 scavenger feed
Feed water
Dissolved oxygen meter/recorder
Chemicals

Carryover

- **Carryover is the entrainment of minute water particles along with steam during steam separation, carrying solid, liquid, and gaseous impurities of water, thereby reducing the purity of the steam. Carryover arises from increasing:**

1. **Concentration of dissolved and suspended solids in drum water**
2. **Steam–water disengagement speed/Steam Drum Pressure**

The solids, thus carried over, then deposit as thin scales In the super heater (SH) tubes, leading to failure due to overheating and On the turbine blades, leading to a loss of output

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Carryover

Volatile Carry Over

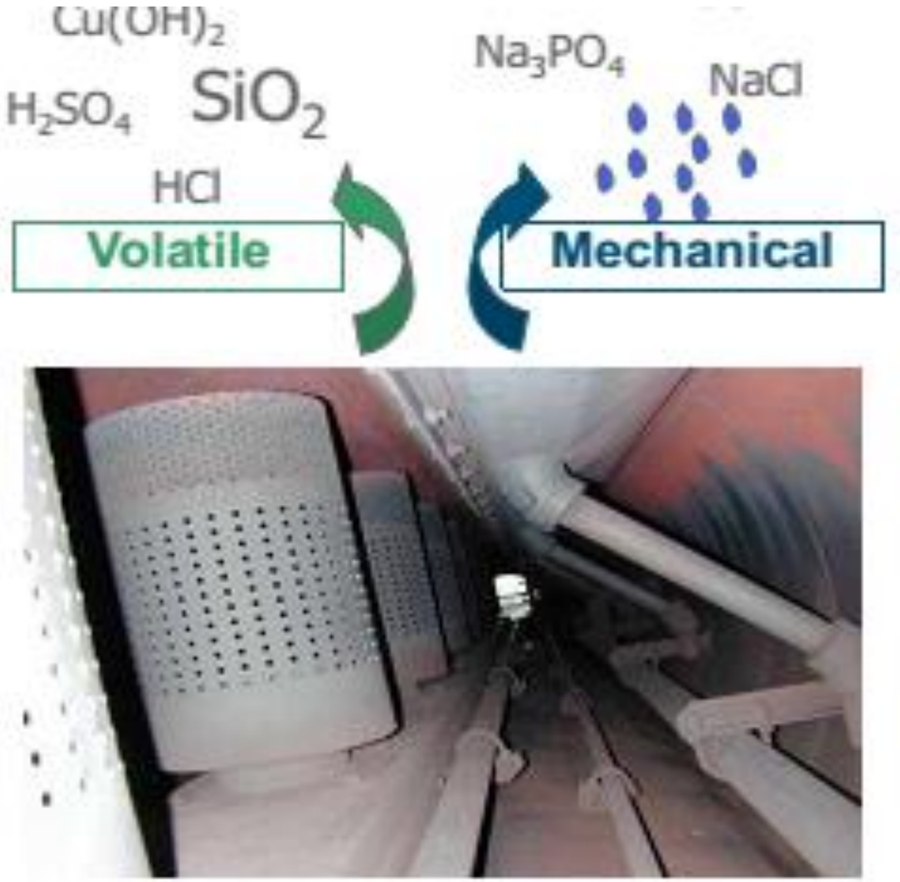
- Higher pressure = greater volatility
- Cu an issue at > 160 bar

Mechanical Carry Over

- Occurs in all boilers all the time
- Drops contain same TDS in boiler water

Contamination via Attemperation

- FW contamination directly to turbine



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Carryover

Corrosion

- **Sodium:** NaOH contributes to SCC in LP turbine
- **Chloride and Sulfate:** HCl and H2SO4 contribute to pitting corrosion and SCC in LP turbine
- **Organic acids:** may contribute to corrosion

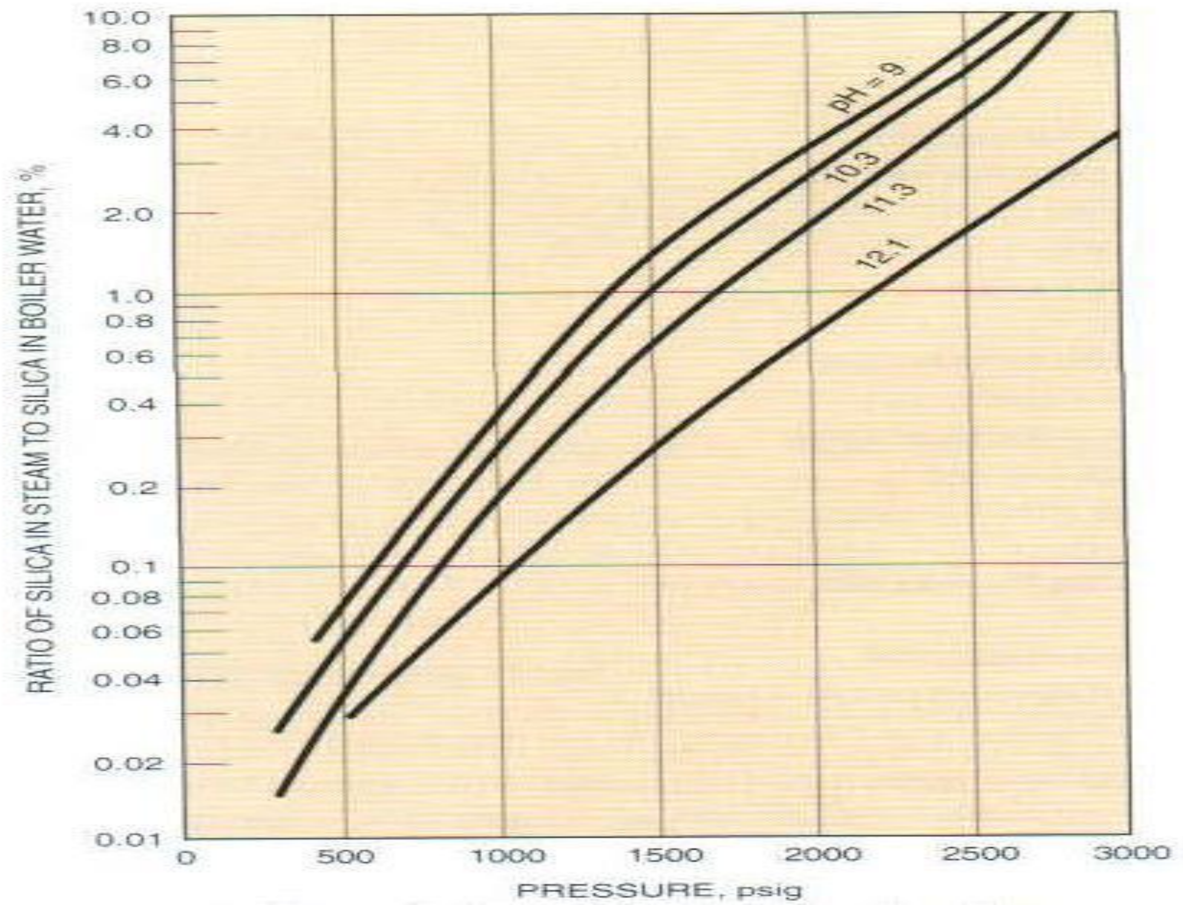
Deposition

- **Silica:** deposition on LP turbine
- **Copper:** deposition on HP steam valves and HP turbine blades
- **Iron oxide:** deposition on all turbine stages, solid particle erosion (SPE)

Volatile Carryover

- Volatility is indicated by a substance's vapor pressure. It is a tendency of a substance to vaporize
- Volatility is indication of a component to be released without external driving force
- Volatility is Related to steam pressure
- Volatility increase with the increase in pressure

Silica Carryover



Thank you