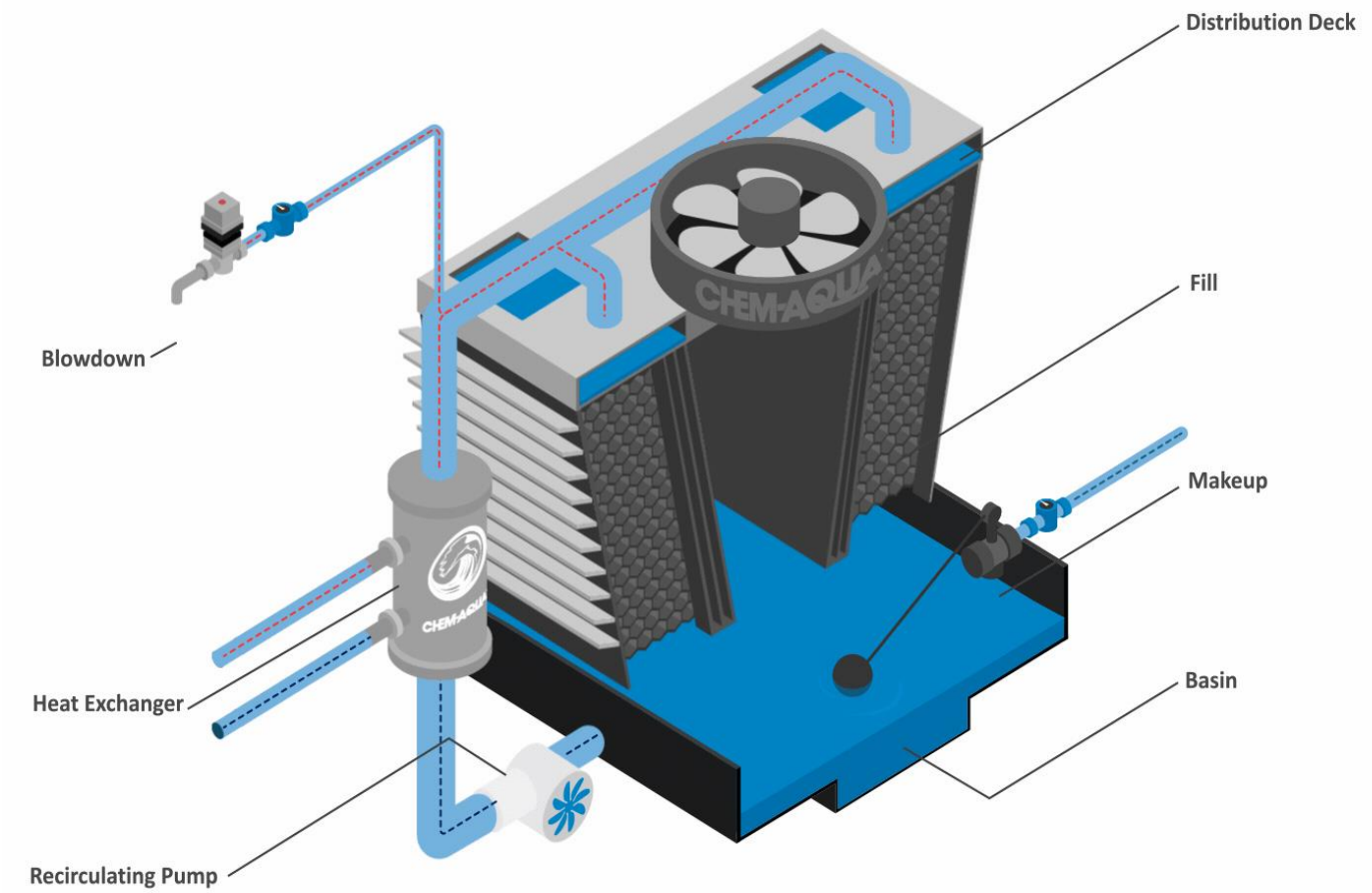
Water Treatment

Industrial utilities

By: Omar Hawass

Cooling Tower

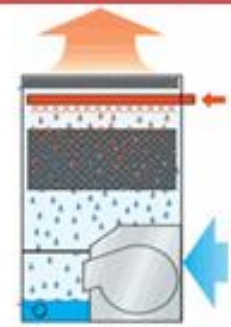
- A device which provides optimum air/water contact in order to cool that water by evaporation”.



Fan Type

Natural Draft

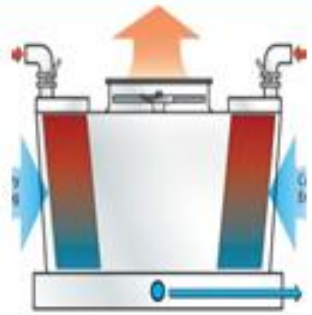
Forced Draft



Induced Draft

Air Flow

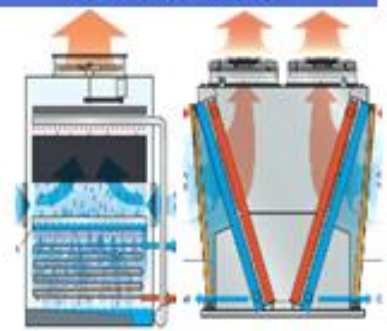
Cross Flow



Counter Flow

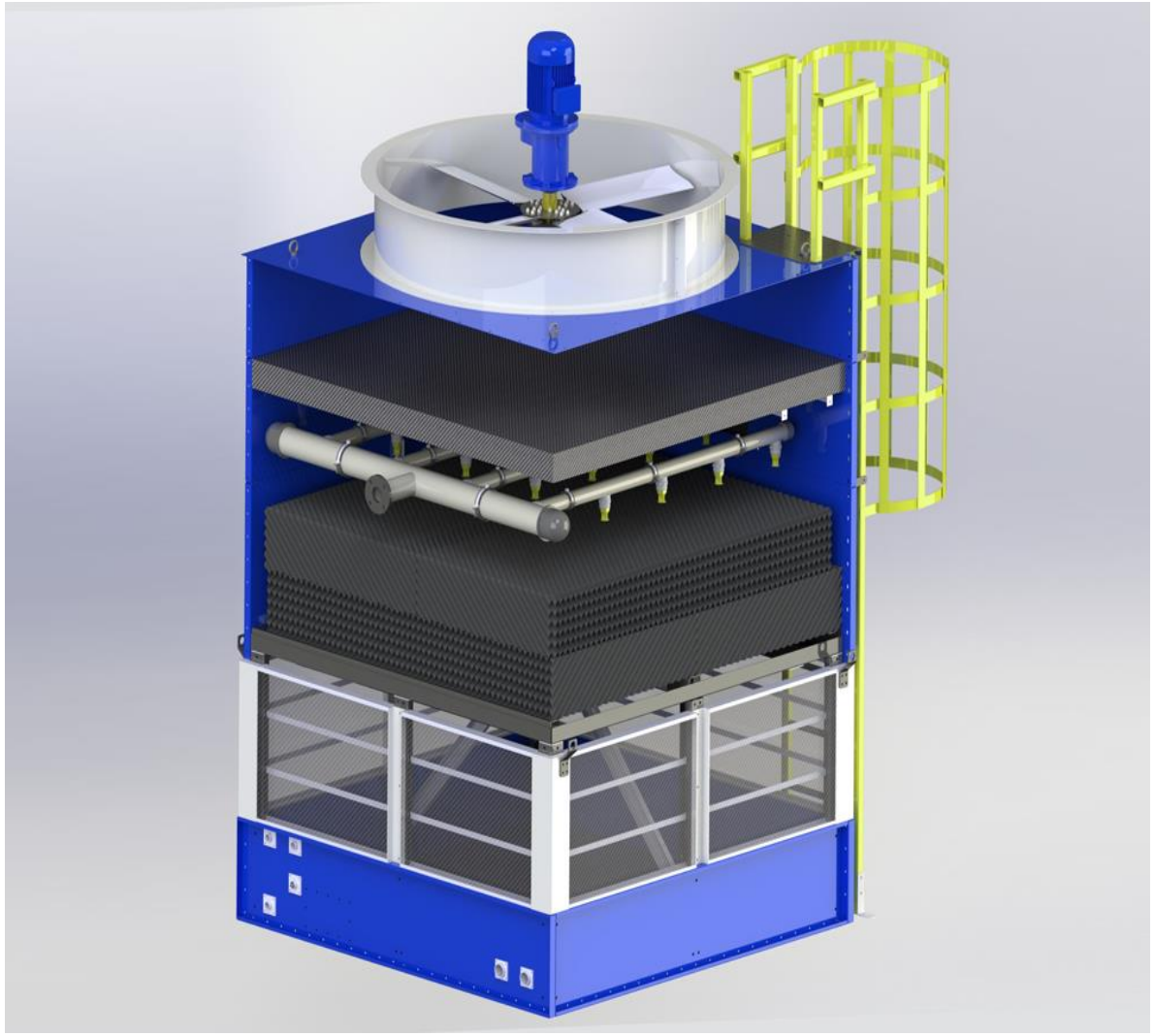
Water Circuit

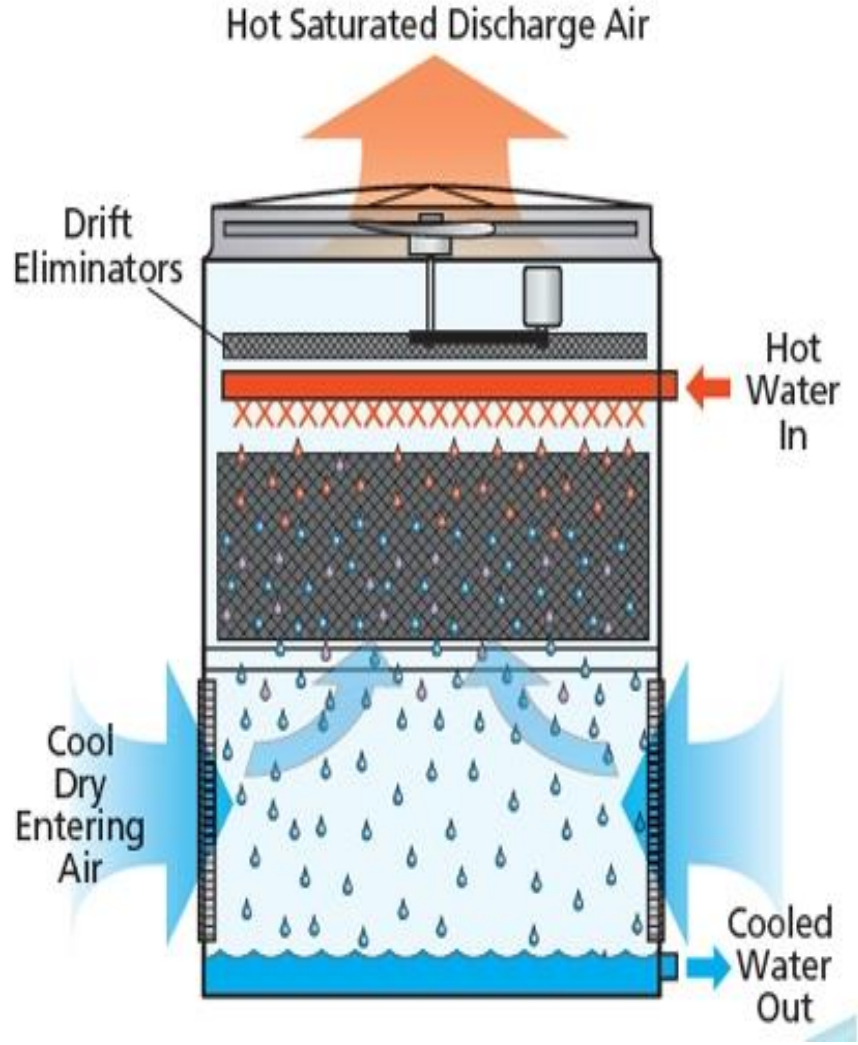
Closed Circuit



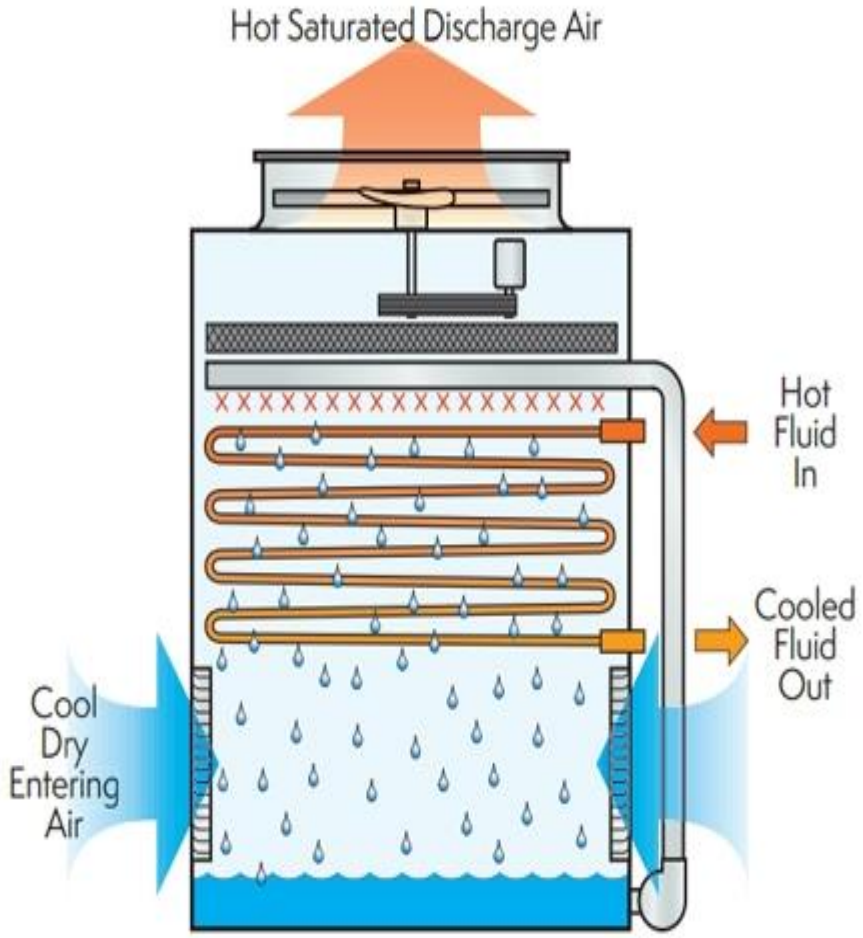
Open Circuit

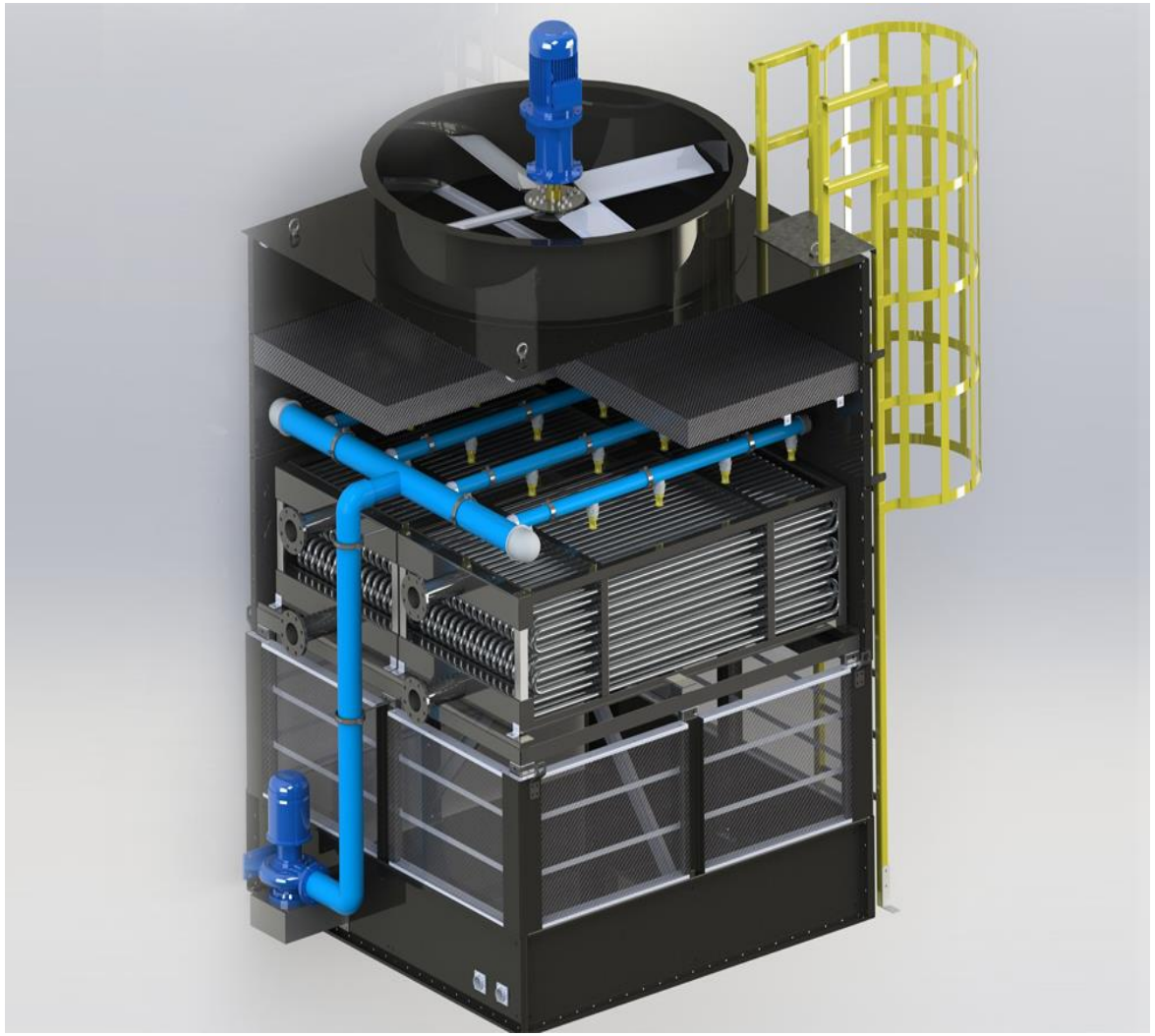
Open Cooling Tower





Closed Cooling Tower EvCond





Cooling Towers Definitions & Calculations

- **Cooling Water Mass Balance**

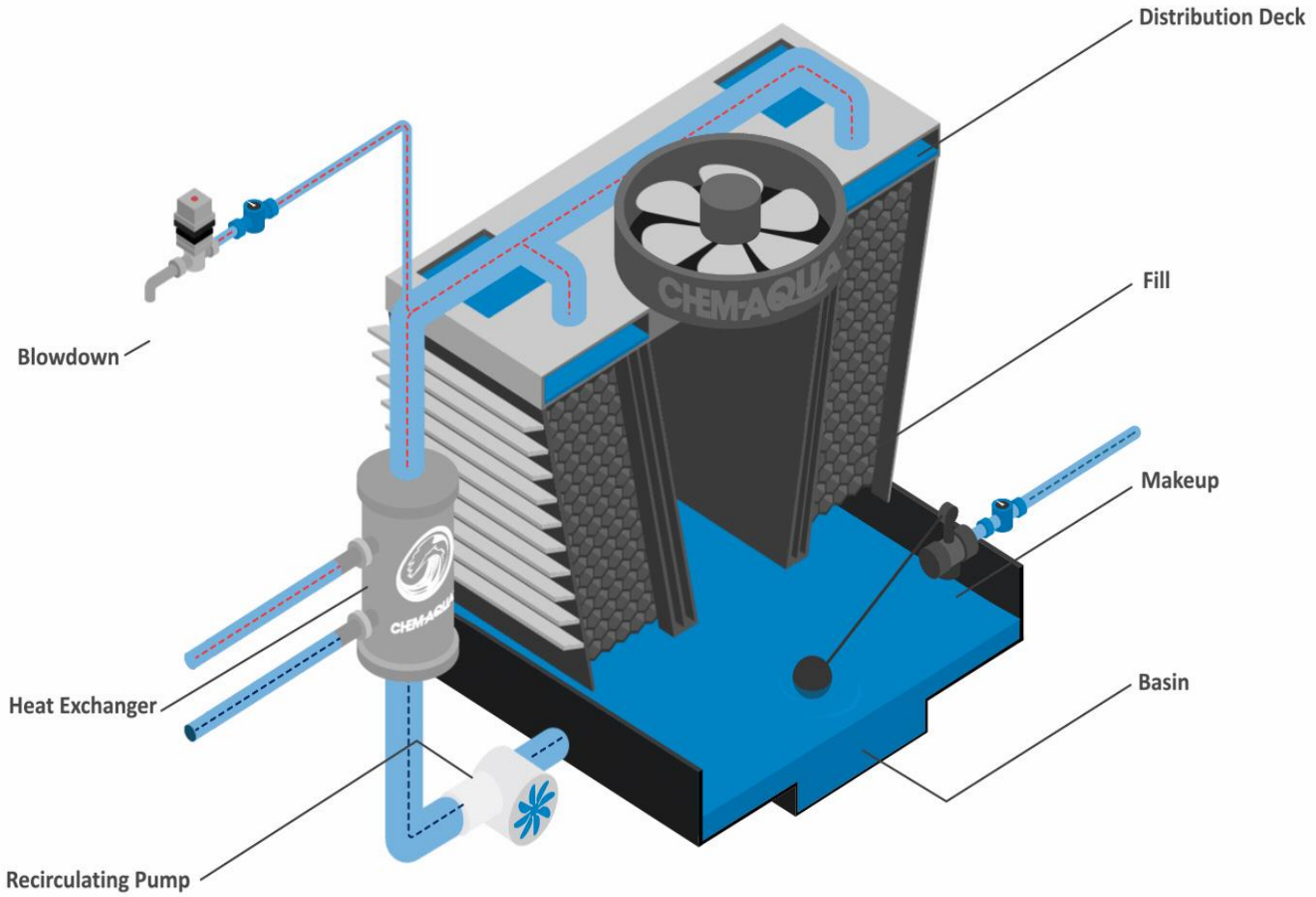
Water is recirculated over a cooling tower and cooled. Makeup replaces water losses.

❖Loss of water occurs from:

Evaporation • Blowdown • Windage

Parameters For Water Calculations

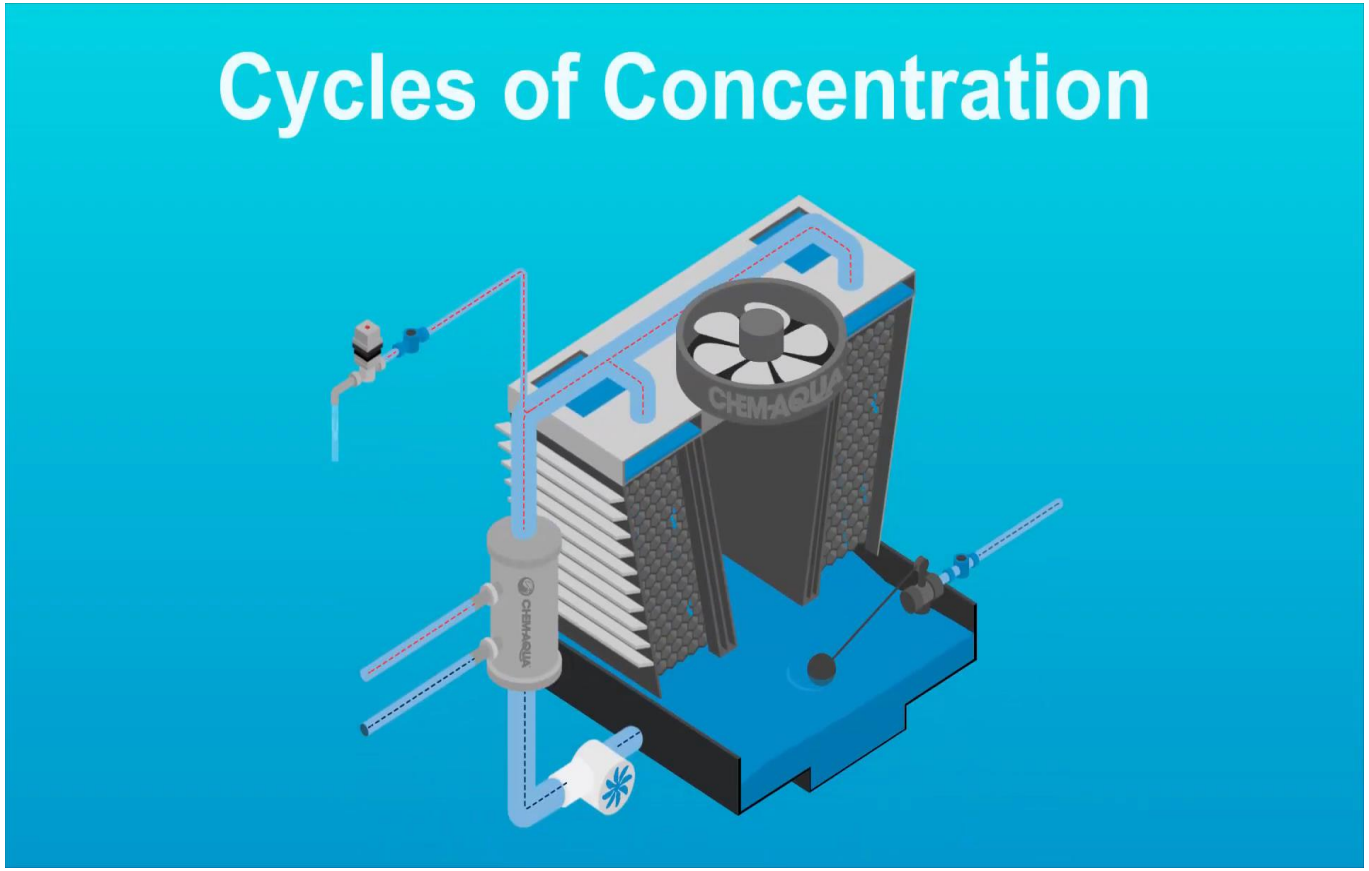
- Make Up Water.
- Re-circulation Rate.
- Temperature Differential (ΔT)
- Evaporation Rate.
- Blow Down Rate.
- Windage Rat



Why Cycle?

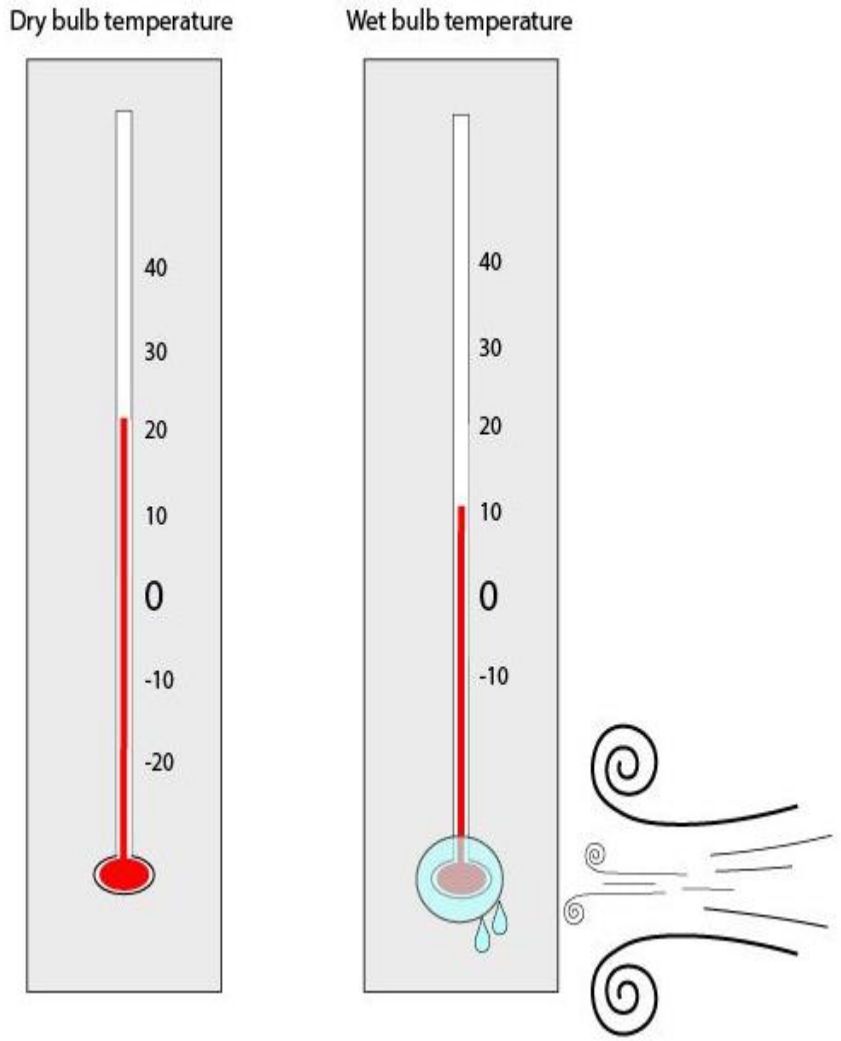
High cycles of Concentration Means :

- Low makeup Rate.
- Low blow-down Rate.
- Cutting total operating cost.



WET BULB TEMPERATUE OF AIR :

- Wet bulb temperature indicates how much water can evaporate into the surrounding air.
- Wet Bulb temperature can be measured by using a thermometer with the bulb wrapped in wet muslin.
- Performance of cooling tower is dependent on the wet bulb temperature. Lower wet bulb temperatures means more evaporation



Water Balanced

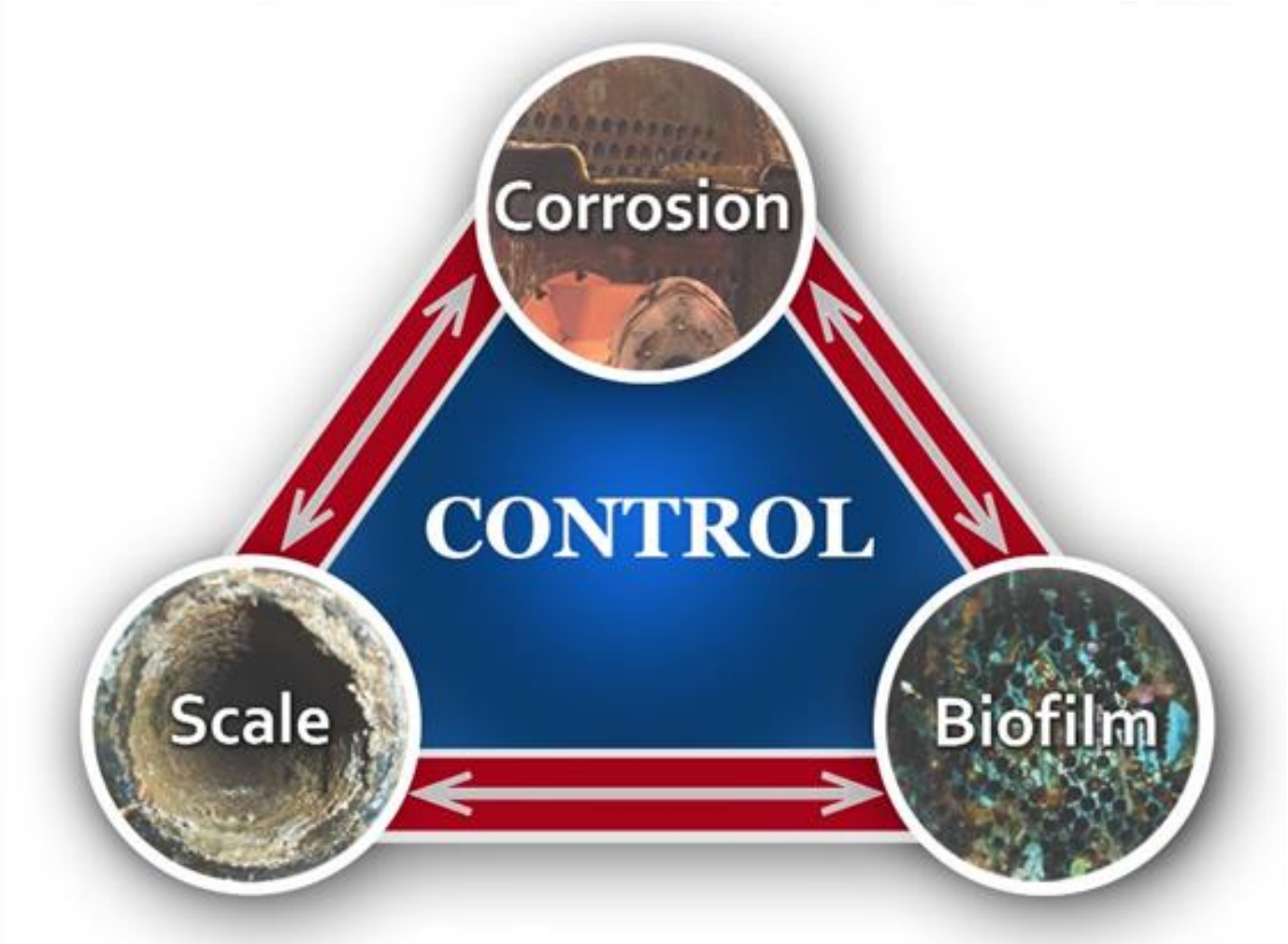
Makeup = Evaporation + Blow-down + Windage

Evaporation Rate = 0.00085*1.8* Re-circulation Rate* ΔT

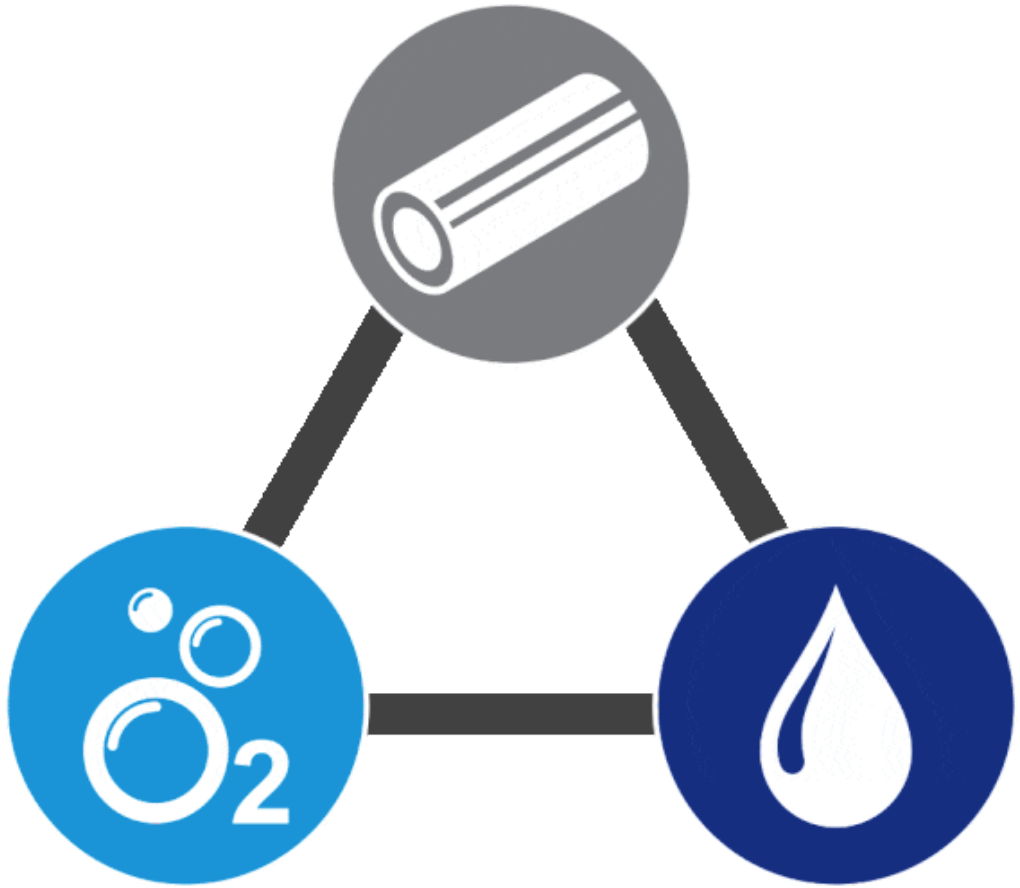
Blow-down + Bleed = Evaporation Rate / (Cycle of Concentration -1)

Cycle of Concentration = TDS Cooling Tower / TDS Makeup

Cooling System Water Problems



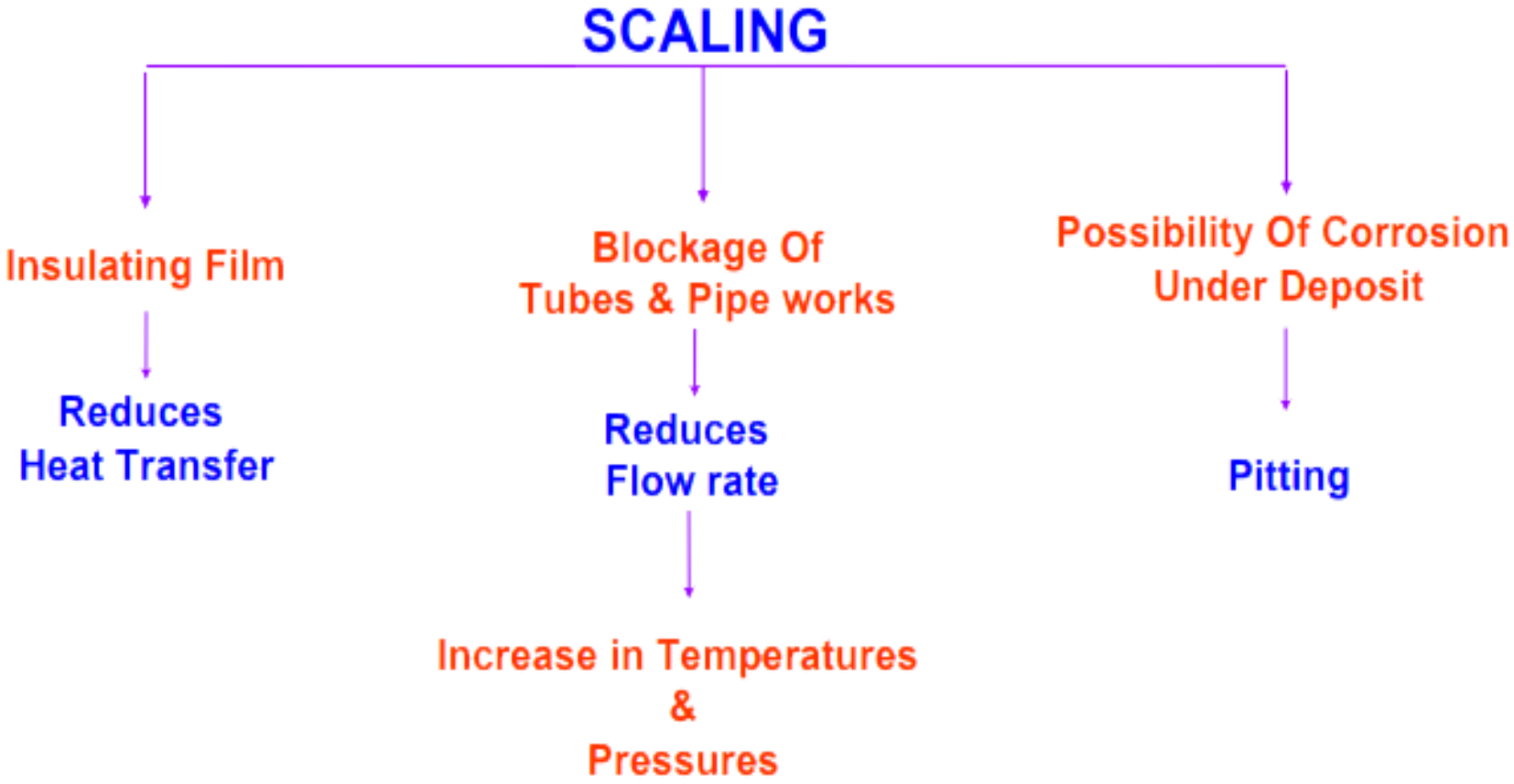
Corrosion



Metal (unprotected) + **Oxygen** (electrochemical potential) + **Water** (electrolyte) = Corrosion

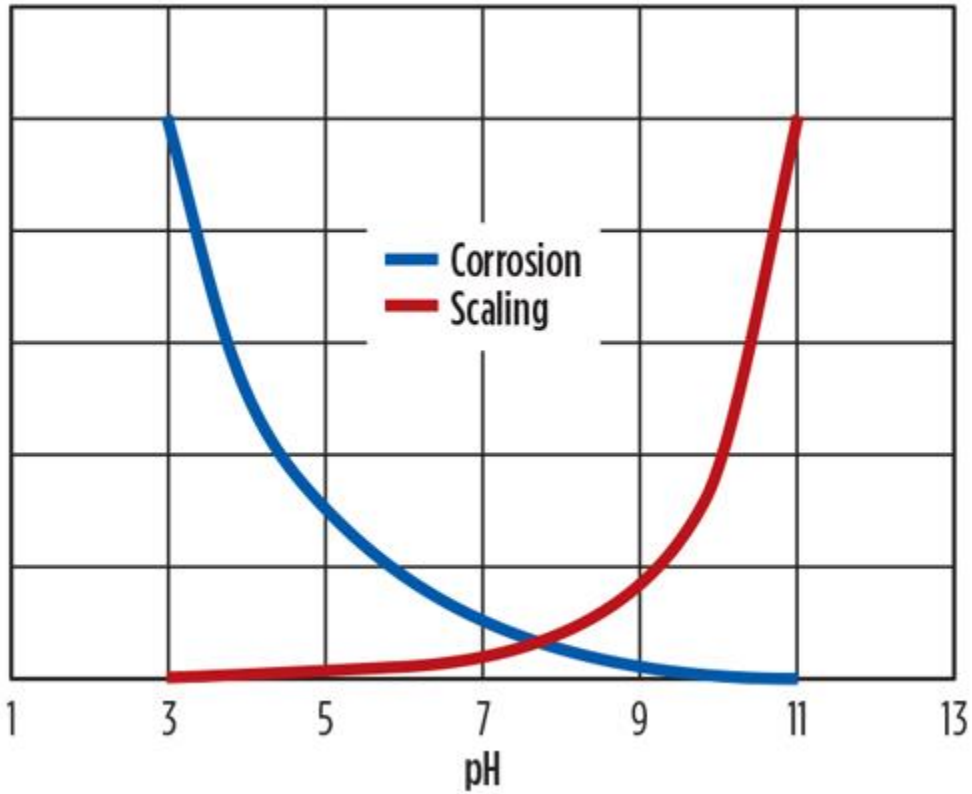
Common Scales

- Calcium Carbonate
- Magnesium Silicate
- Calcium Phosphate
- Calcium Sulfate
- Iron Oxide
- Iron Phosphate



Factors Affecting Corrosion Rate

- Temperature
- PH
- Water velocity
- Product Solubility
- Metallurgy



Mechanism To Control Scale Cooling Tower

- 1.**Threshold Effect** Chemicals which , when used is sub-stoichiometric amount is capable of preventing the precipitation of salts from a supersaturated solution.

- 2. **Crystal Growth Inhibition / Crystal Distortion**. Chemical interference to normal crystal growth produces irregular crystal structure with poor scale forming ability

- 3. **Dispersion** : Chemical which can adsorb onto scale surface causing the particles to remain in suspension

Biofouling Control

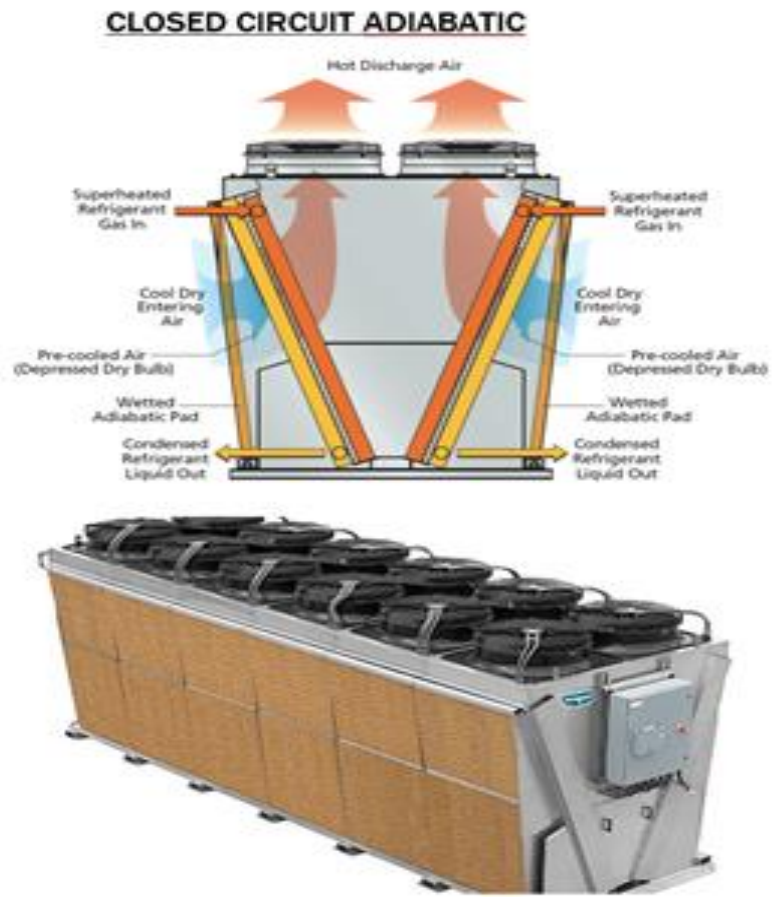
- $Cl_2 + H_2O \Leftrightarrow HOCl + HCl$
- Hypochlorous acid (HOCl), is the killing agent, and it functions by penetrating cell walls and oxidizing internal cell components. The efficacy and killing power of this compound are greatly affected by pH because of the equilibrium nature of HOCl in water

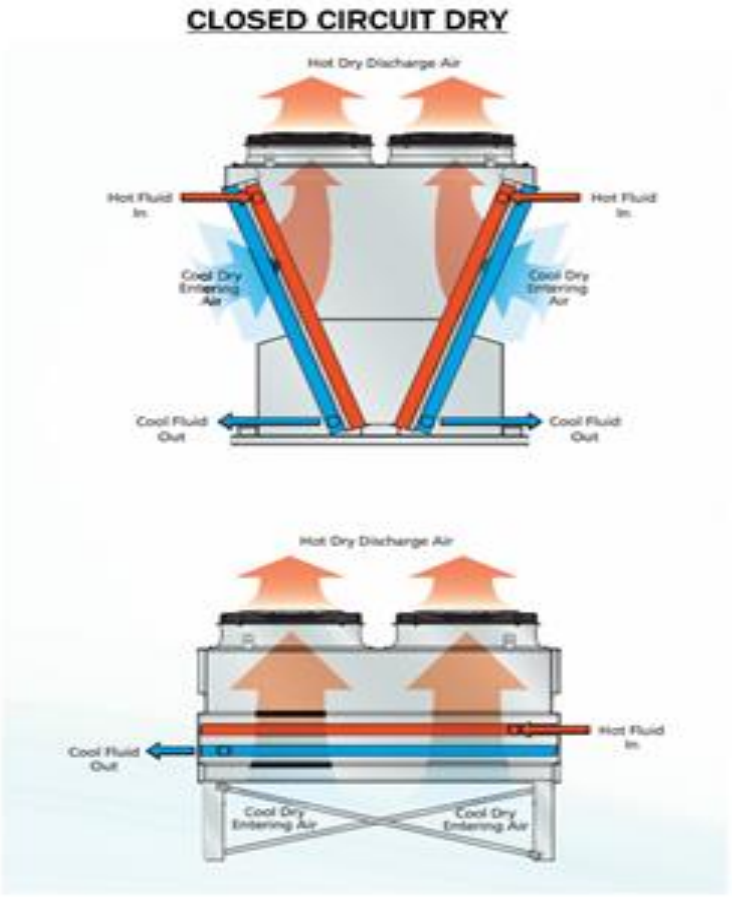
- Nonoxidizing biocides work through various processes. These biocides interfere with reproduction, stop the respiration process, or break the cell wall. They are generally shot-fed to achieve a high enough concentration for a long enough period to kill the bacteria, algae, or fungi. Kill time generally requires several hours up to a day. In some cases

Biocides Treatment

- both biocides are used together in many conditions such as cooling water systems.
- When using a nonoxidizing microbicide in combination with an oxidizing agent, there should be a slight to no residual oxidant concentration present in the system at the time of addition.
- Sufficient time should be given for the nonoxidizing microbicide to work before resuming oxidant feed unless an oxidant compatible microbicide is being used

Closed Loop

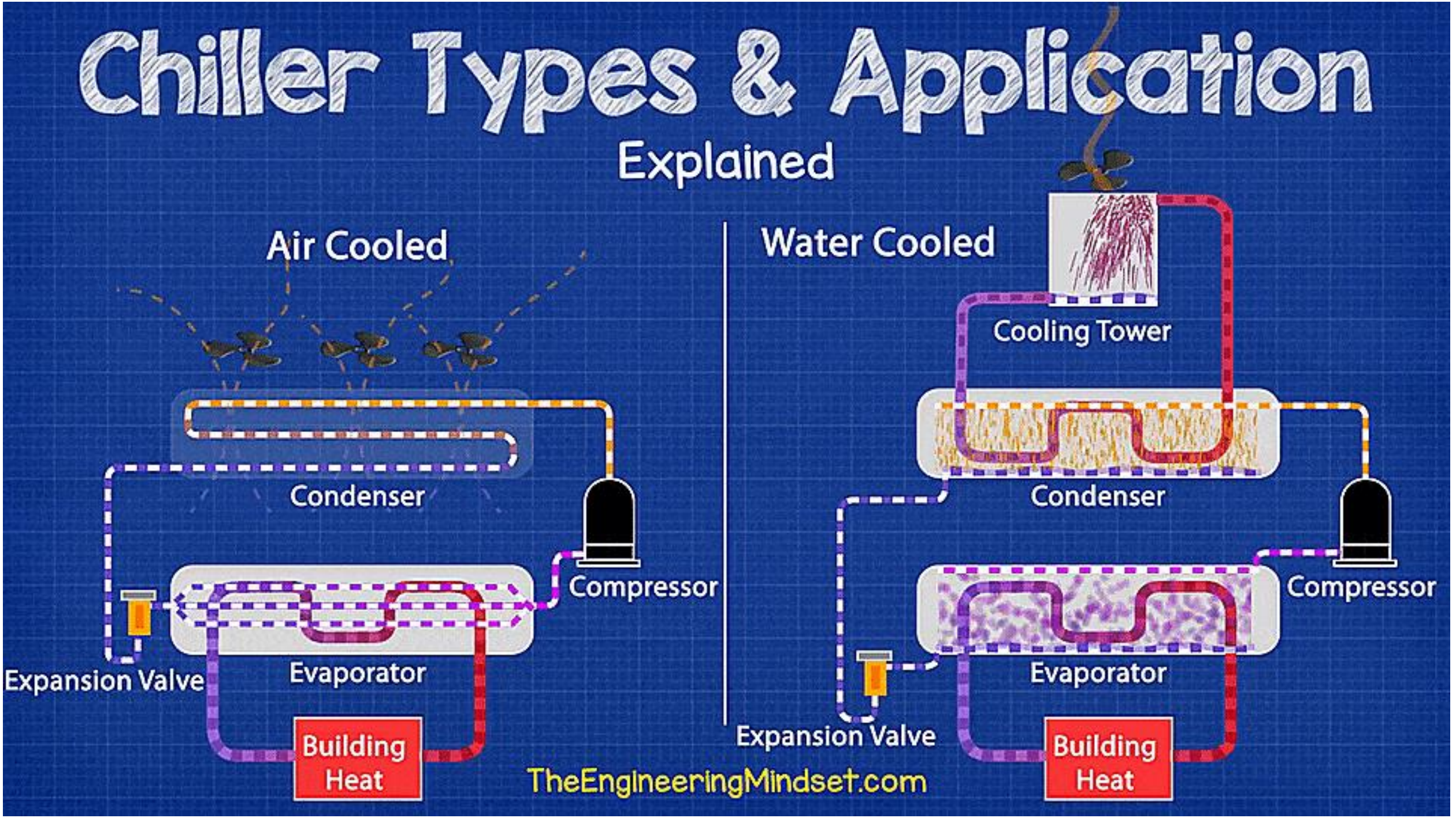




Closed loop water systems can be used to cool or heat an area or process.

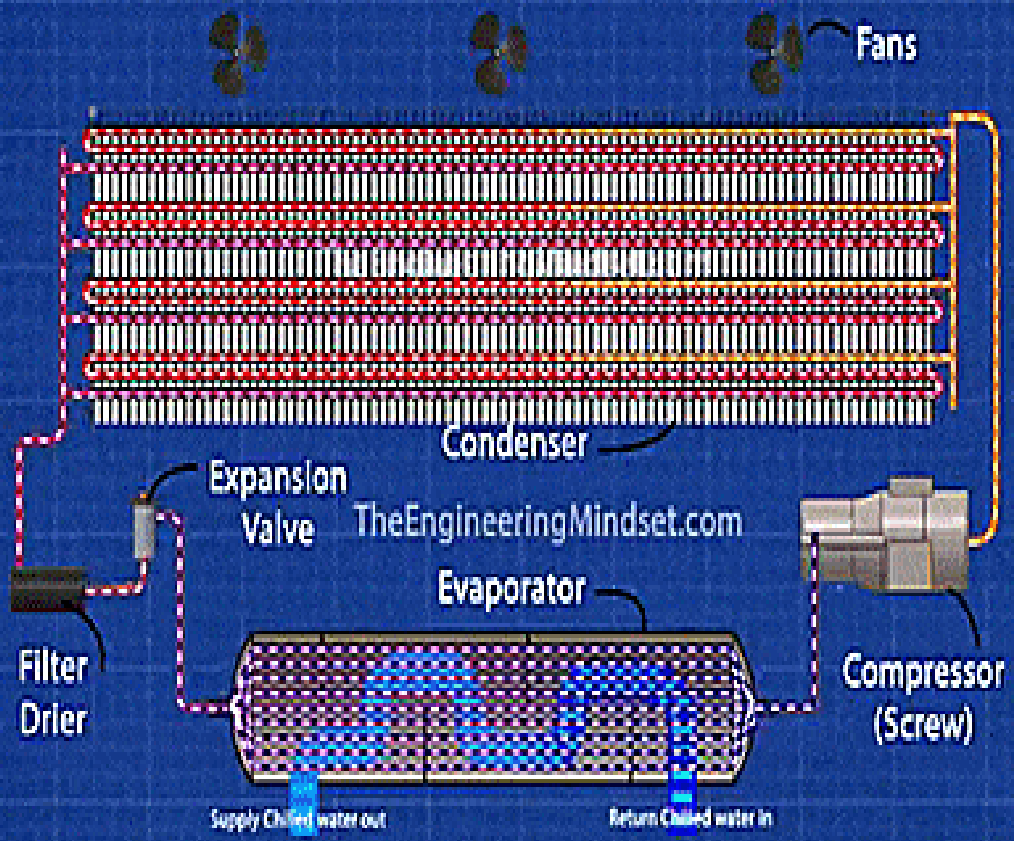
Chiller Types & Application

Explained



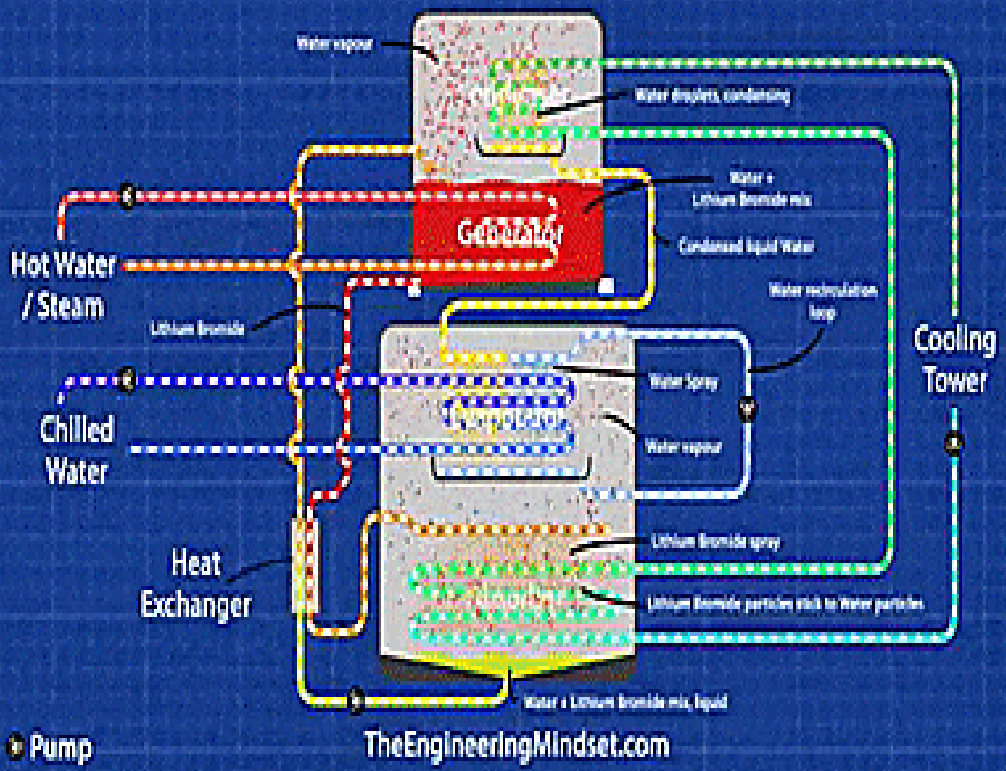
TheEngineeringMindset.com

Vapor-compression



Uses an electrically driven mechanical compressor to force a refrigerant around the system

Vapor-absorption



Uses a heat source such as steam or hot water to move the refrigerant around the system

Closed Systems

- Water loss is usually less than 0.5% of the system volume in a year.
- No water loss – no makeup.
- No concentration of solids so scale is generally of no concern.
- Corrosion controlled by establishing a good film barrier.

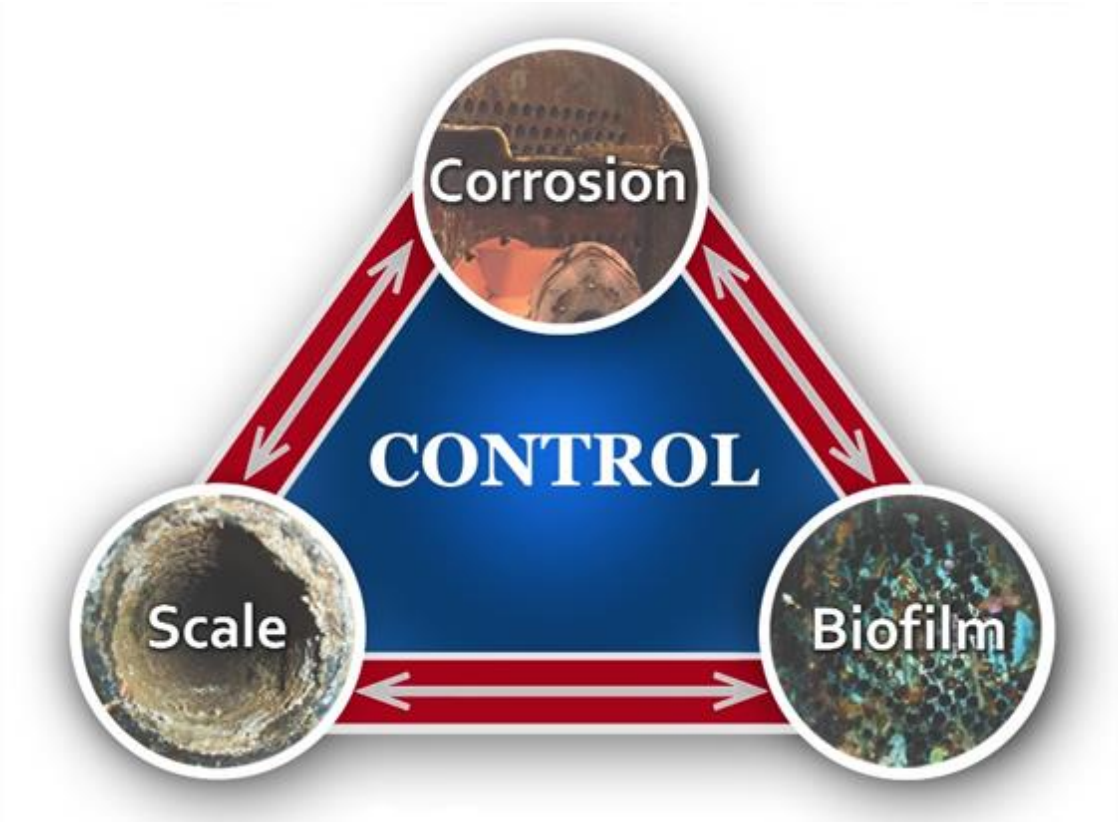
Closed System Water Problems

Cold System

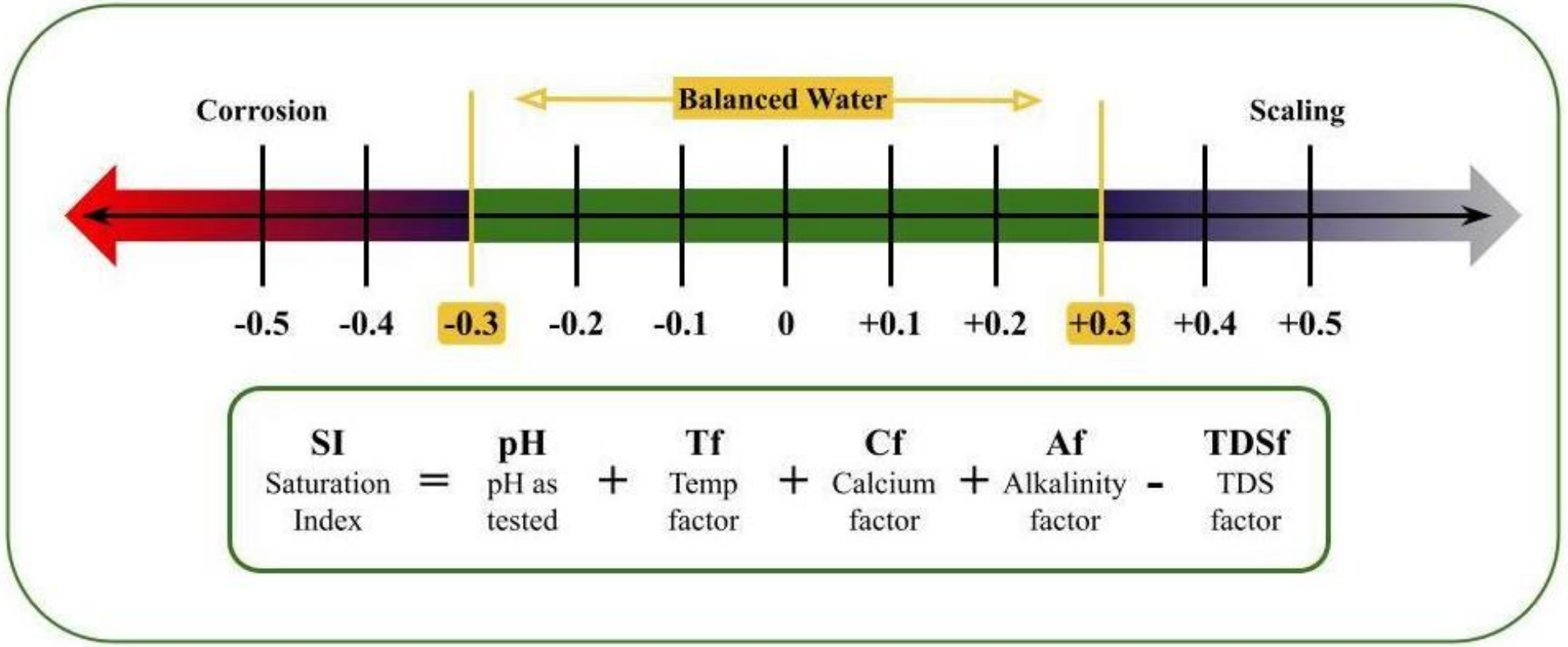
- Corrosion
- Biofilm

Hot System

- Corrosion
- Scal



Langelier Saturation Index

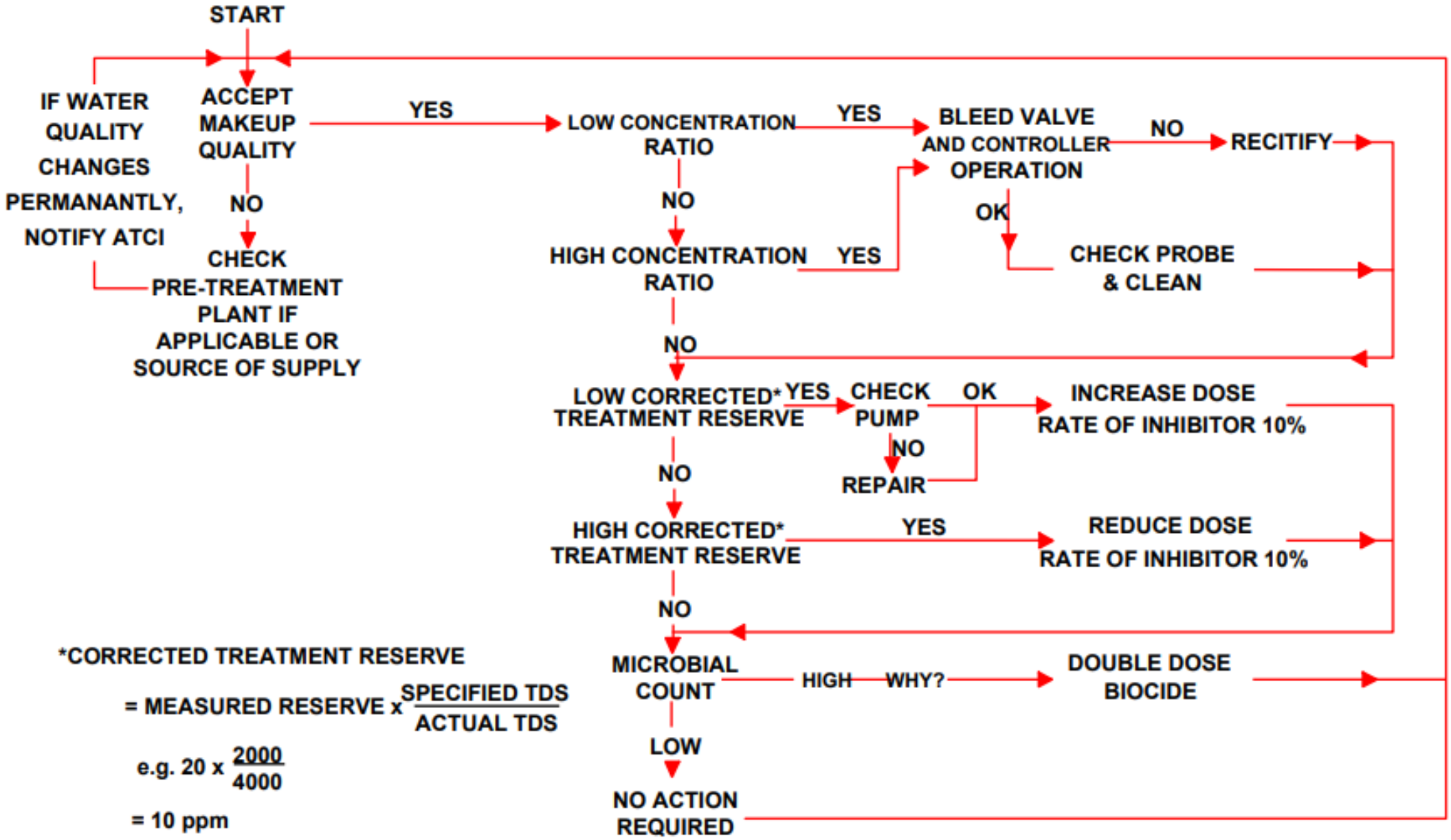


[langelier saturation index (lenntech.com)]

Recommendation Limits in Cooling Tower

CHEMICAL CONTROL LIMITS		Makeup Water for Cooling Tower		
Parameter		City Water	Softener	RO
pH	8.5 – 9.2	7.4	7.5	7.2
Conductivity uS/cm	1500	360	370	10
TDS ppm	1000 – 800	250	260	5
M-Alkalinity, ppm CaCO3	Av 600	150	Zero	Zero
Calcium Hardness, ppm CaCO3	Av 450	130	Zero	Zero
Total PO4, ppm	4 - 7			
LSI	<0.25	-0.17		
CR	3.5 - 4	3.5 - 4		

What if ? Cooling Tower

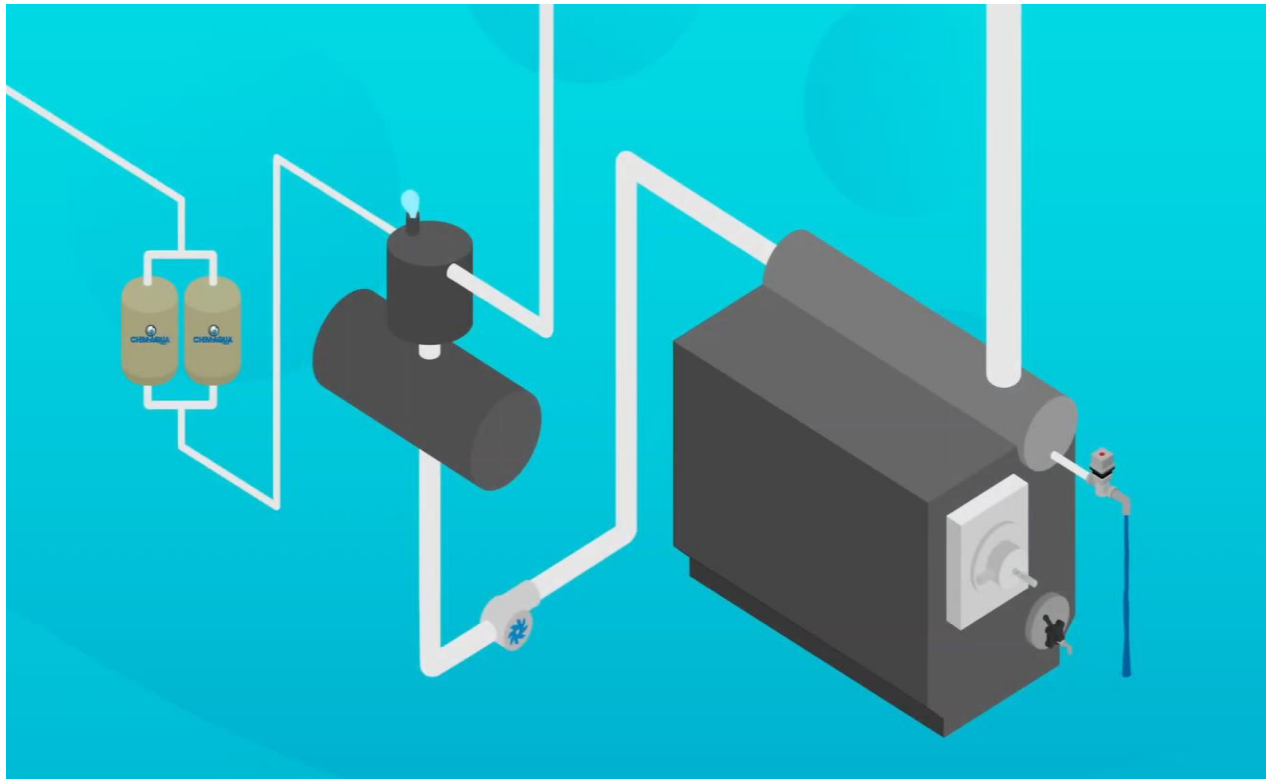


Recommendation Limits in Closed System

CHEMICAL CONTROL LIMITS		Makeup Water for Closed System		
Parameter		City Water	Softener	RO
pH	8.5 – 9.2	7.4	7.5	7.2
Tannin	Av 1000	150	Zero	Zero
Nitrite	Av 1000	130	Zero	Zero
Total PO4, ppm	4 - 7			
LSI	<0.25	-0.17		

Boiler

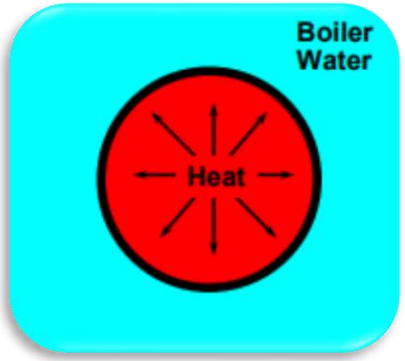
- Heating
- As Raw Material
- Motive Force
- Cleaning/Disinfection/Sterilisation



Types of Steam Boile

- Fire Tube

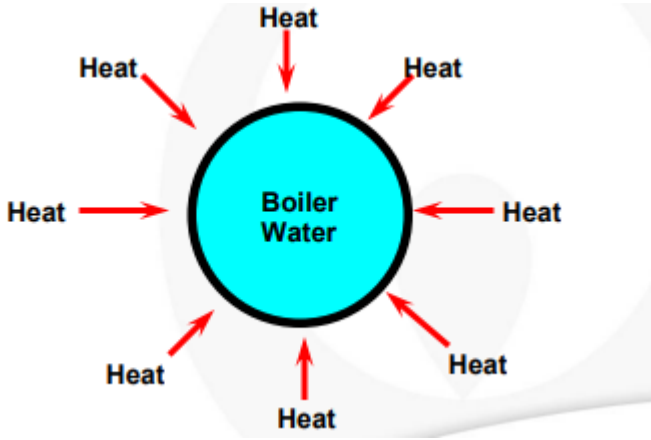
(Heat Source inside tubes, water in pressure vessel heated by tubes



- Water Tube

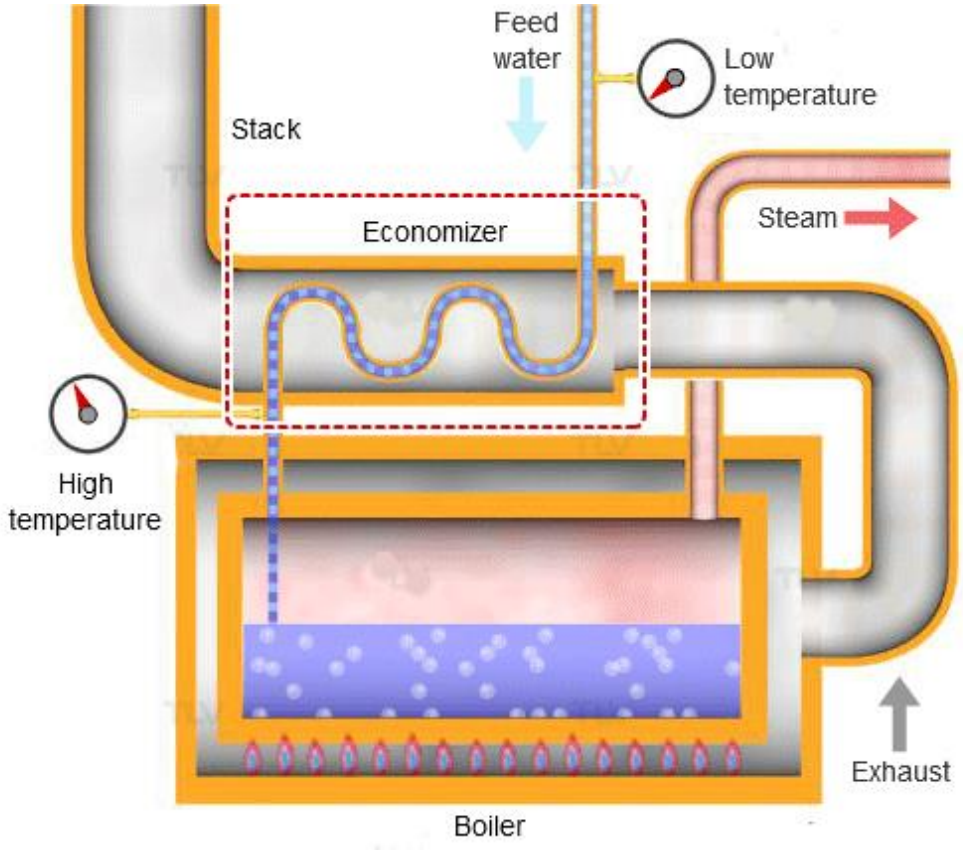
(Heat source on outside, water enclosed in tube)

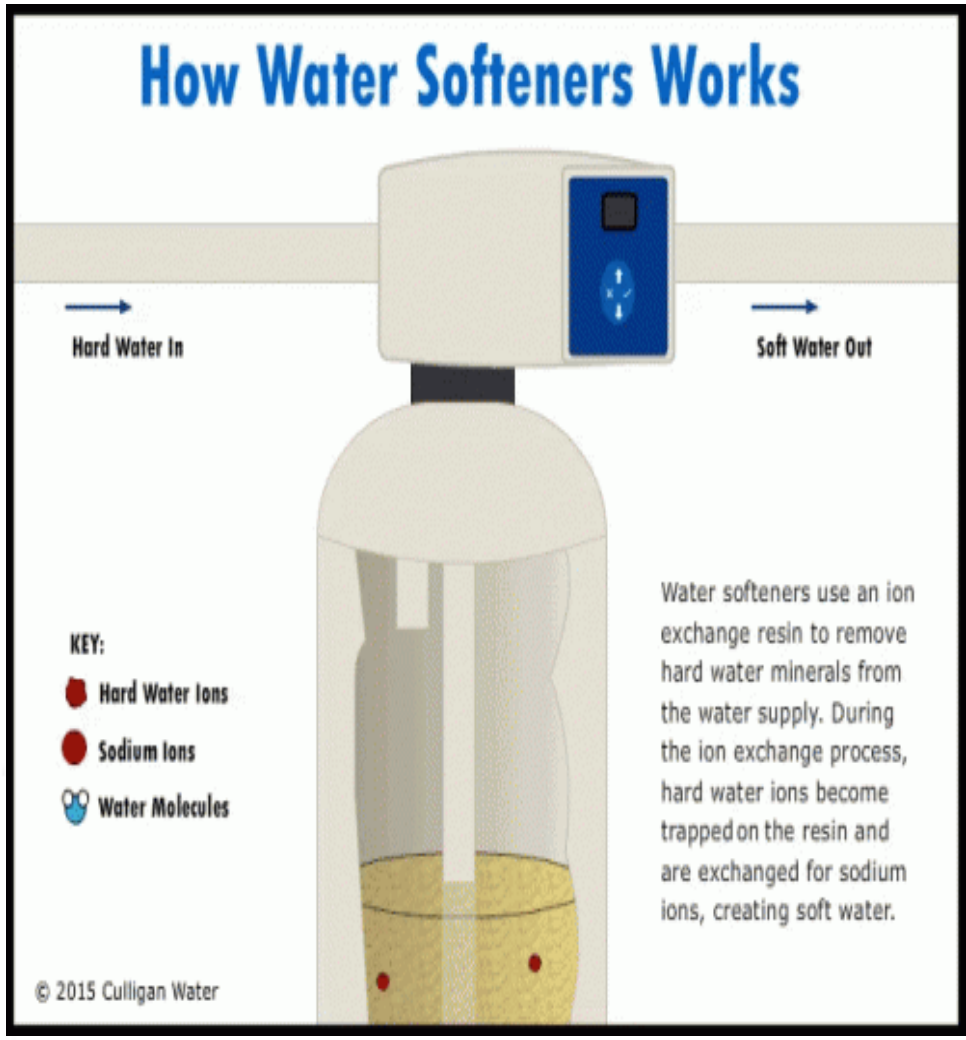
- Coil Water Tube



External Methods

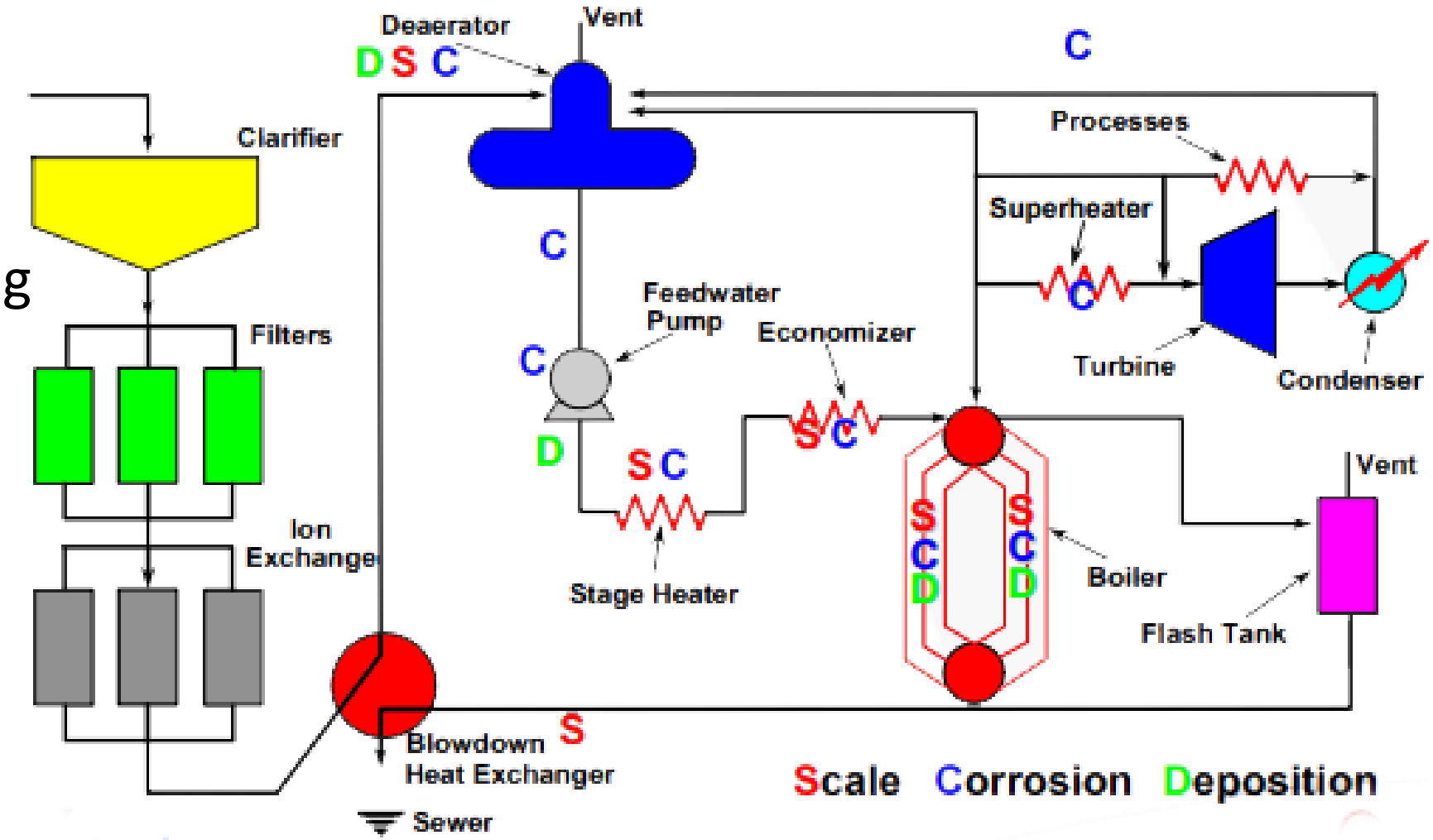
- Softening
- Reverse Osmosis
- De-Aeration
- Economizers





Boiler System Problems

- Scale
- Corrosion
- Deposition/Fouling
- Carryover
- Condensate

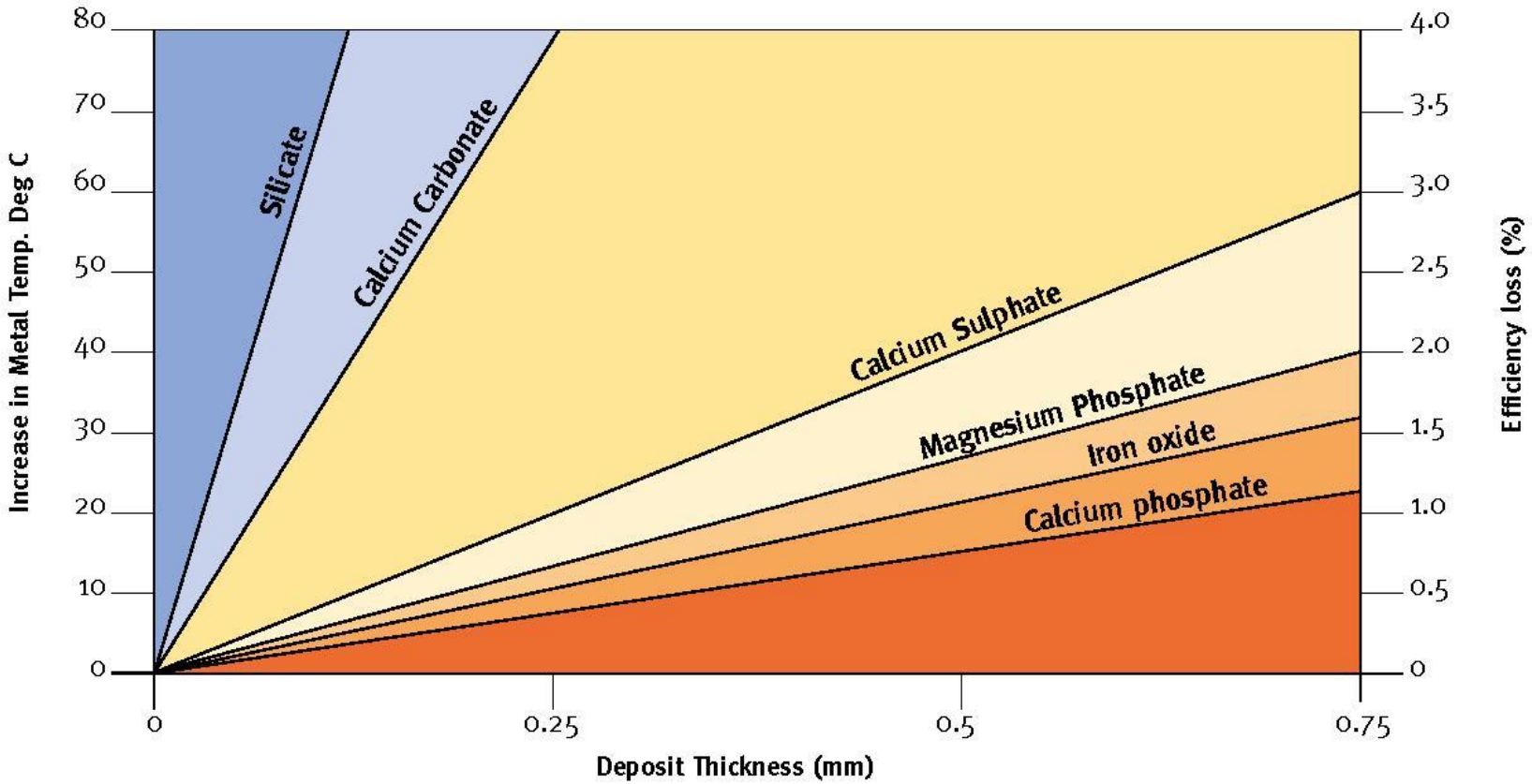


Scale can lead to

- Loss of efficiency
- Higher fuel consumption
- Blockages
- Tube failure

Extract from Good Practice Guide 221

Improving boiler energy efficiency through water treatment



Graphical Representation of the effects of scale on boiler efficiency

Chemical constituents of boiler scale can be any one or a combination of all of the above

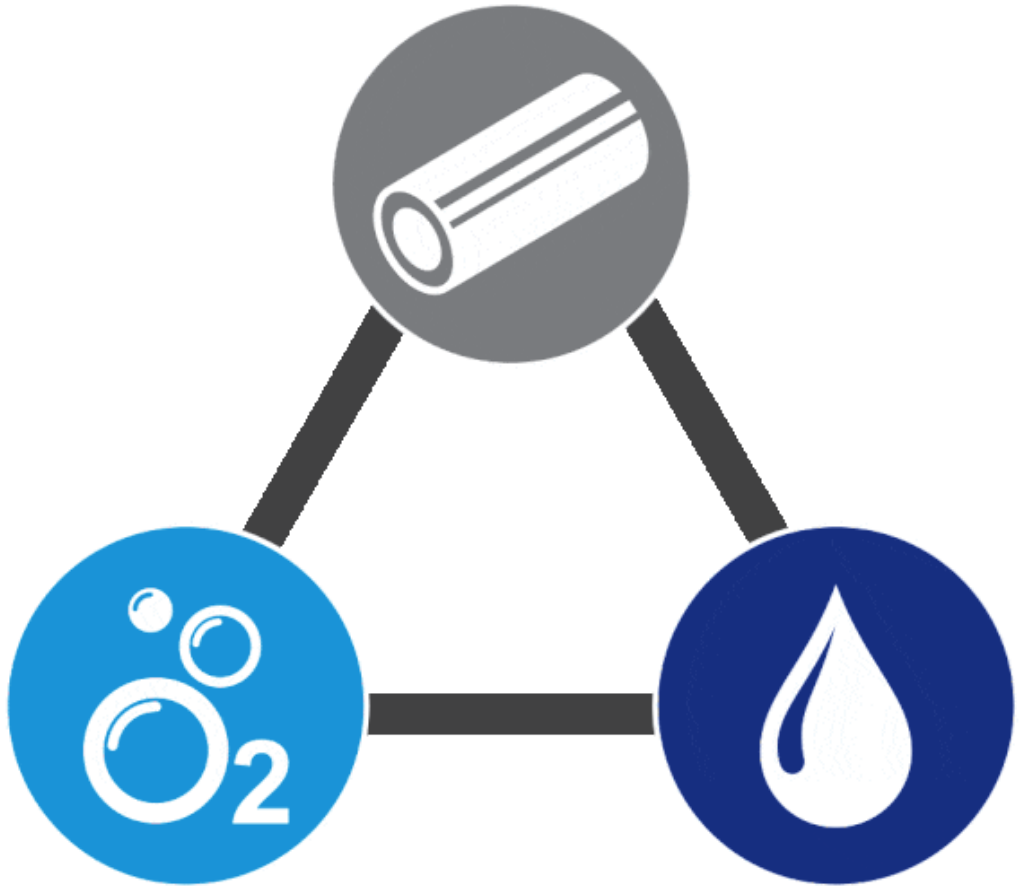
Solution of Scale

- Softener / RO
- Add Chemical Such as (Phosphate , Polymers)
- 1. **Distortion**. The crystal structure of any existing scale or precipitated hardness salts is completely distorted (or modified)-resulting in readily dispersible deposits/ precipitates .

- 2. **Dispersion**. The distorted scale deposits or hardness precipitates are dispersed, being kept in free suspension in the boiler water until they are eventually removed by the normal blowdown process .

- 3. **Threshold**. Threshold agents act in less than stoichiometric concentrations to prevent or retard the precipitation of scale forming units .

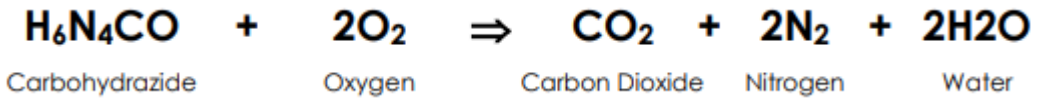
Corrosion



Metal (unprotected) + **Oxygen** (electrochemical potential) + **Water** (electrolyte) = Corrosion

Solution of Corrosion

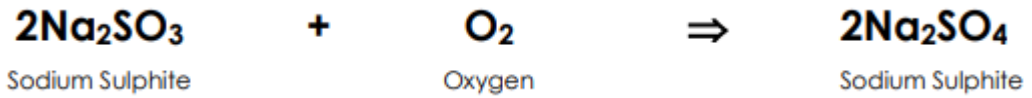
- **Carbohydrazide**



(at a rate of 0.7 ppm per 1 ppm of oxygen scavenged)

Carbohydrazide cannot be used in applications where the steam comes into contact with food or food packaging.

- **Sodium Sulphite**



(the reaction is 10 ppm of sodium sulphite are required to react with 1 ppm of oxygen)

Sulphite is an effective oxygen scavenger, but it is non-volatile

- **Erythorbic acid (EA)**

product a GRAS (generally Regarded As Safe) status for applications

where the boiler water may come into contact with food production

- **Tannins**

conditioners and are effective as corrosion inhibitors since they reinforce the protective magnetite film

used effectively in systems with cold feed water

Condensate Corrosion

- Oxygen is in solution in the boiler feed water. Carbon dioxide is also dissolved in the feed water, as well as being produced by the thermal decomposition of carbonate and bicarbonate salts inside the boiler

$$Ca(HCO_3)_2 + Heat \Rightarrow CaCO_3\Downarrow + CO_2\Uparrow + H_2O$$

Calcium Bicarbonate — Calcium Carbonate — Carbon Dioxide — Water

- If the makeup water is softened, then the reaction becomes :

$$2NaHCO_3 + Heat \Rightarrow Na_2CO_3 + CO_2\Uparrow + H_2O$$

Sodium Bicarbonate — Sodium Carbonate — Carbon Dioxide — Water

- At higher temperatures and pressures, a different reaction takes place :

$$NaHCO_3 + Heat \Rightarrow 2NaOH + CO_2\Uparrow$$

Sodium Bicarbonate — Sodium Hydroxide — Carbon Dioxide

- Double the quantity of carbon dioxide is generated if the second reaction occurs. Therefore, as boiler pressure (and hence temperature) increases, so does the quantity of carbon dioxide generated . When the steam condenses, oxygen and carbon dioxide dissolve in the water and produce a dilute carbonic acid solution containing oxygen.

$$CO_2 + H_2O \Rightarrow H_2CO_3$$

Carbon Dioxide — Water — Carbonic Acid

- This solution, being very aggressive, will attack steel pipes and even copper

Water Balanced

Makeup = Steam + Blow-down

Boiler Steam Rate	4.00	T/Hr
Operating Hrs	24.00	Daily
Operating Days	7	week
Operating Hrs	8,736.00	Year
Feed Water TDS	70.00	ppm
Boiler BD TDS	2,000.00	ppm
Cycle	28.57	
Feed Water Temp	104.00	oC
Dissolved Oxygen	0.50	PPM
daily Fuel Consumption - gas	4,500.00	Cubic meter
Actual Steaming Rate	60.00	Daily
Steaming Rate	2.50	T/Hr
Blow Down	0.09	T/Hr
Actual Feeding Rate	2.59	T/Hr

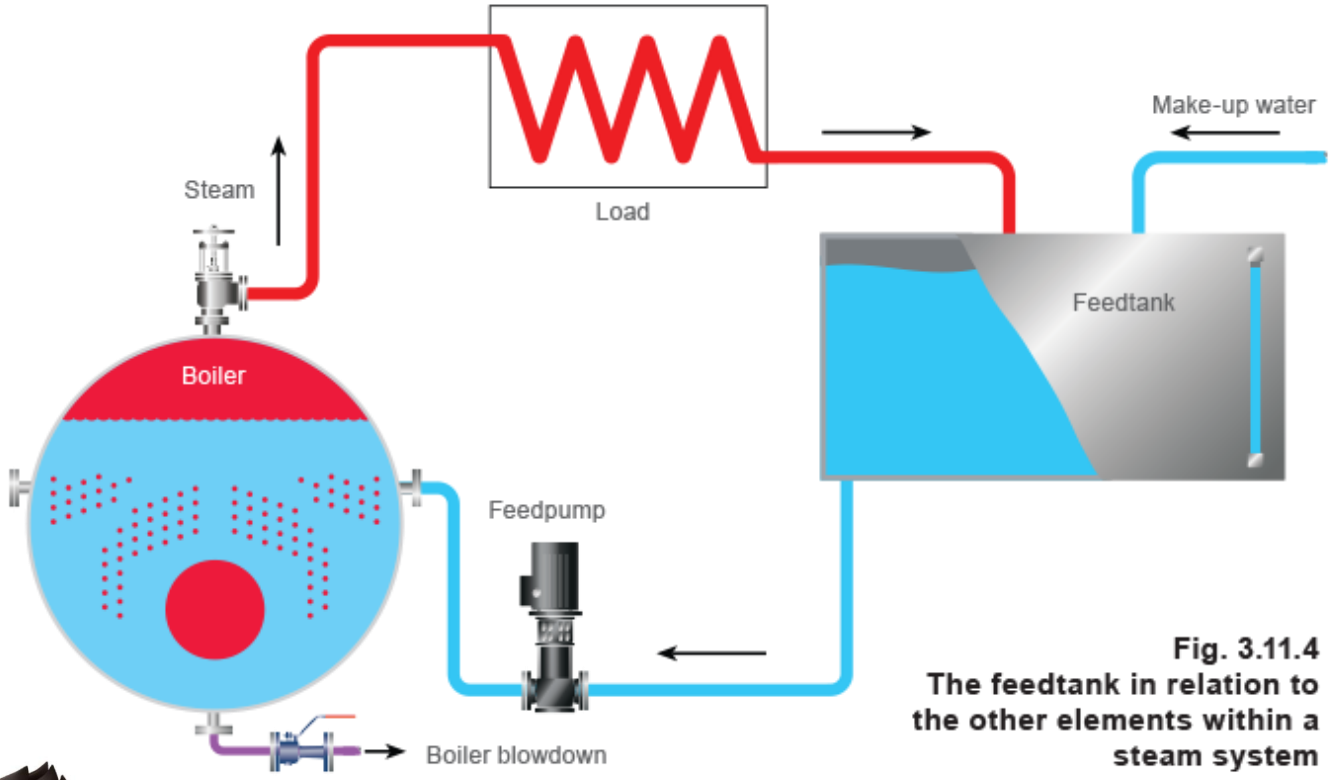
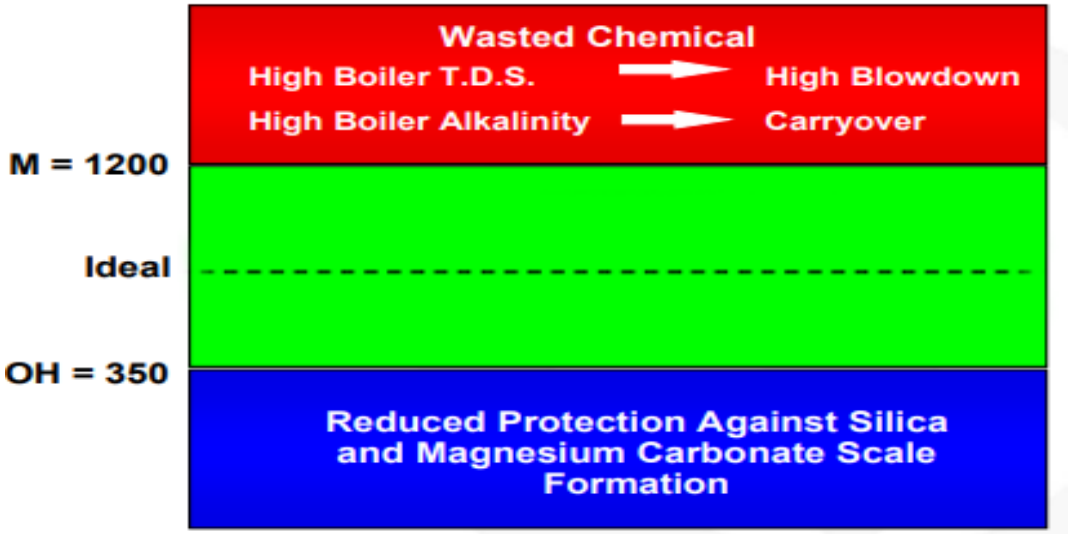
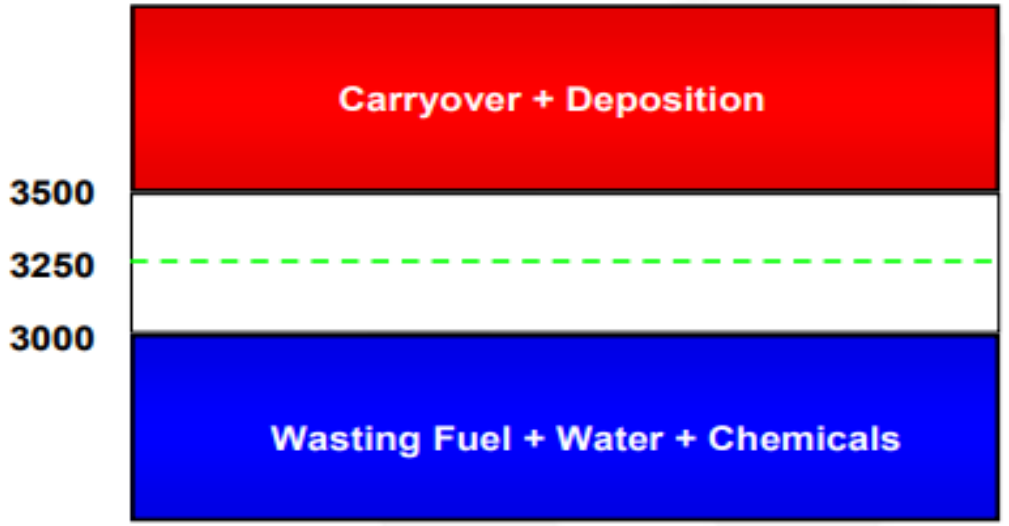


Fig. 3.11.4
The feedtank in relation to the other elements within a steam system

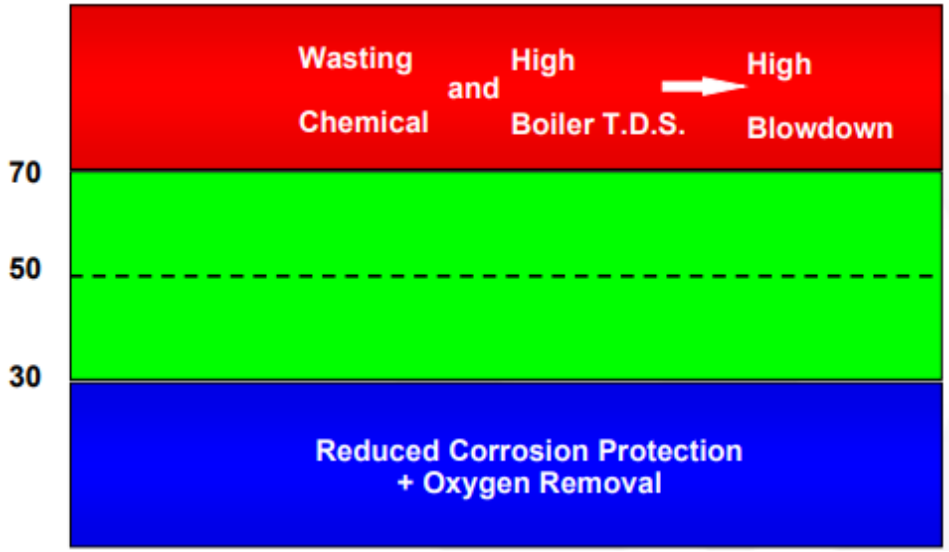
Effects of Boiler Control



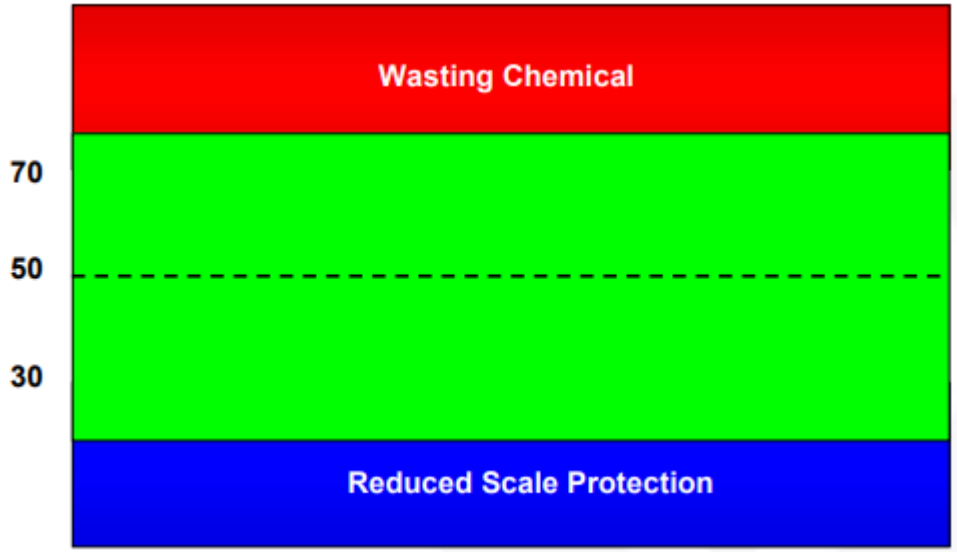
Effects of Alkalinity Control



Effects of T.D.S. Control



Effects of Oxygen Scavenging (Sulphite) Control



Effects of Phosphate Control

Typical Boiler Sampling & Testing Regime

Sample	Analysis	Reason
Main Water	T.D.S. Hardness pH	To Check variability of supply
Treated water at each stage	Hardness Alkalinity (P+M) T.D.S. Ph	To check treatment plant operation is satisfactory. Also used to check condensate return.
Feed Water	pH	Low → Corrosive
	Hardness	Contamination or poor treatment plant operation
	T.D.S.	Condensate return
	Alkalinity (P+M)	Condensate treatment Dosing neutralising Amine
	Temperature	For oxygen scavenger Dosing
Boiler Water	Oxygen scavenger reserve	Low → Corrosion / High → Waste
	Phosphate reserve	Low → Scale forming / High → Waster
	'M' Alkalinity	Low → Corrosion / High → Carryover
	'OH' Alkalinity	Low → Scaling / High → Carryover
	T.D.S.	Low → Waste / High → Carryover
	pH	Low → Corrosive
Condensate	pH	Low → Corrosive / High → Carryover
	T.D.S.	High → Carryover
	Iron	High → Corrosion

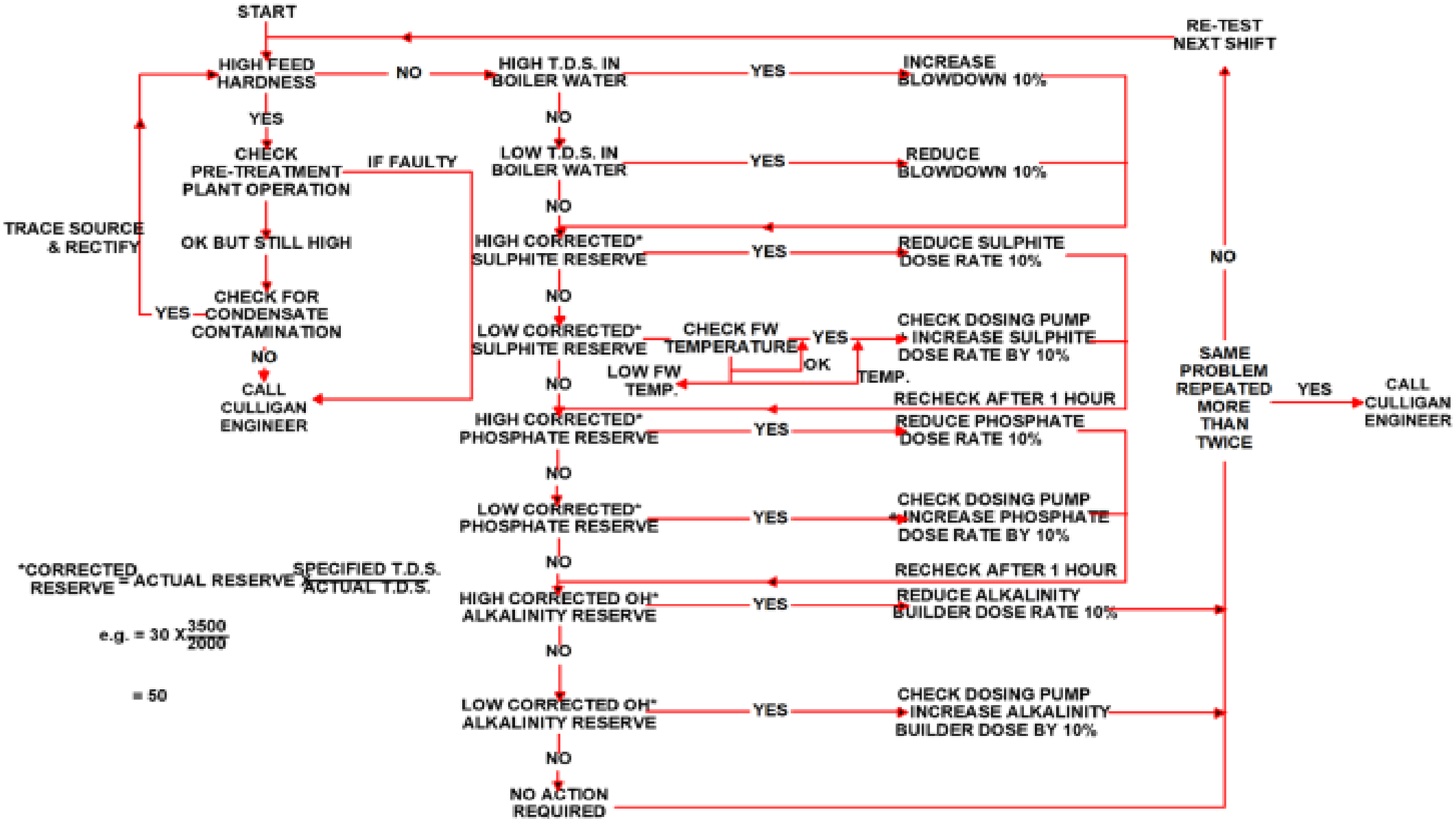
Recommendation Limits in Boiler System

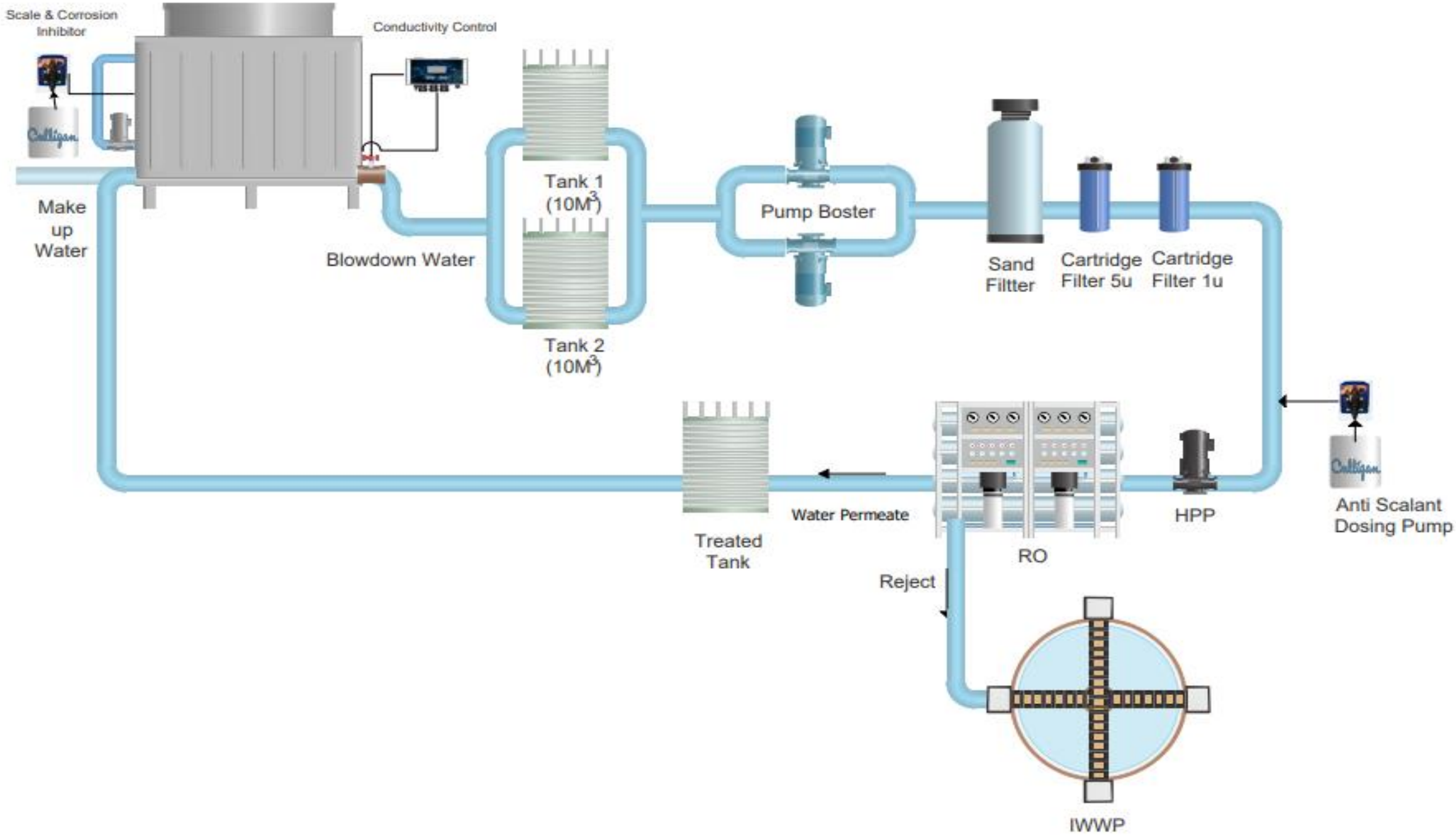
CHEMICAL CONTROL LIMITS				
Parameter	Softener	Boiler Feed Tank	Boiler	Condensate
pH		7.4-8.5	10.5 – 11.5	8.5
TDS ppm		250	260	Zero
M-Alkalinity, ppm		150	1000 Max	
P-Alkalinity, ppm			700 Max	
OH-AlKalinity, ppm			450 Max	
Hardness, ppm	Zero	130	Zero	Zero
Total PO4, ppm			20 - 40	
Total SO3, ppm		-0.17	20 - 40	
Tannin			120 - 160	
CR				

Storage of Idle Boilers

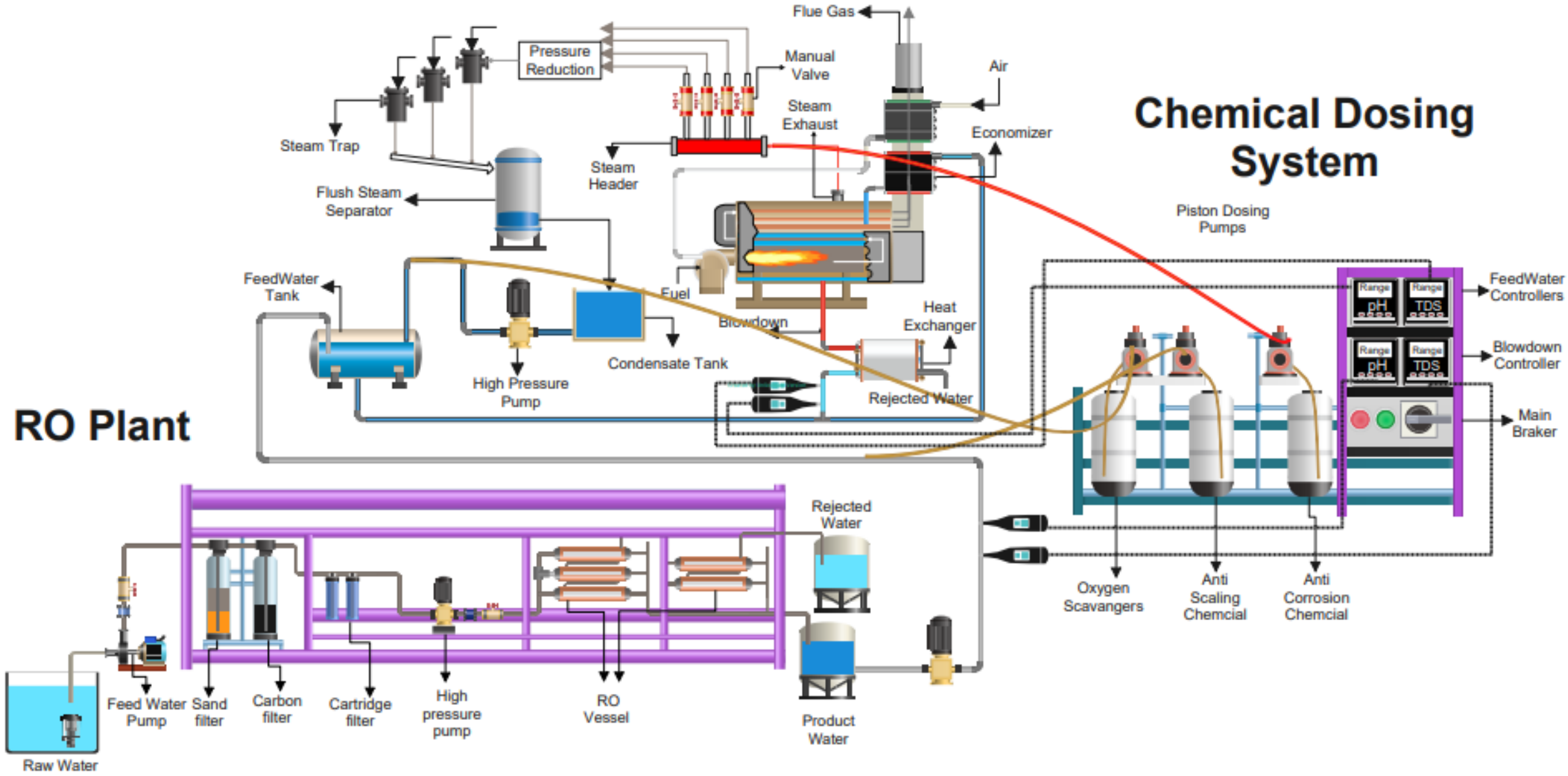
Duration of Boiler shutdown	Storage Method	Storage Treatment
A few days	"Wet Method"- boiler maintained at normal water level.	Normal water treatment maintained.
Up to 3 months	"Wet Method"- boiler fully flooded.	Completely fill the boiler with water and exclude air. The water should then be treated with catalyzed sodium sulphite to give a minimum reserve of 150 ppm sulphite, together with an alkali to give a pH of 10 - 12. These levels should be checked regularly and adjusted as required.
Over 3 months	"Dry Method" with ventilation or drying agent.	See above.

What if ? Boilers




Scale & Corrosion Inhibitor
Conductivity Control
Make up Water
Blowdown Water
Tank 1 (10M3)
Tank 2 (10M3)
Pump Boster
Sand Filtter
Cartridge Filter 5u
Cartridge Filter 1u
Anti Scalant Dosing Pump
HPP
RO
Water Permeate
Treated Tank
Reject
IWWP

Boiler FeedWater Chemcial Dosing System



شكرا لكم على حسن أستماعكم

أتمنى أن أكون عند حسن ظنكم

لا تنسونا من صالح دعائكم

ألقاكم في مرات قادمة بأذن الله