fundamental Water treatment –
Basic Track Cooling water system

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HORIZON
ACADEMY
INDUSTRIAL TRAINING ACADEMY

Horizon Chemical
For Special Chemicals

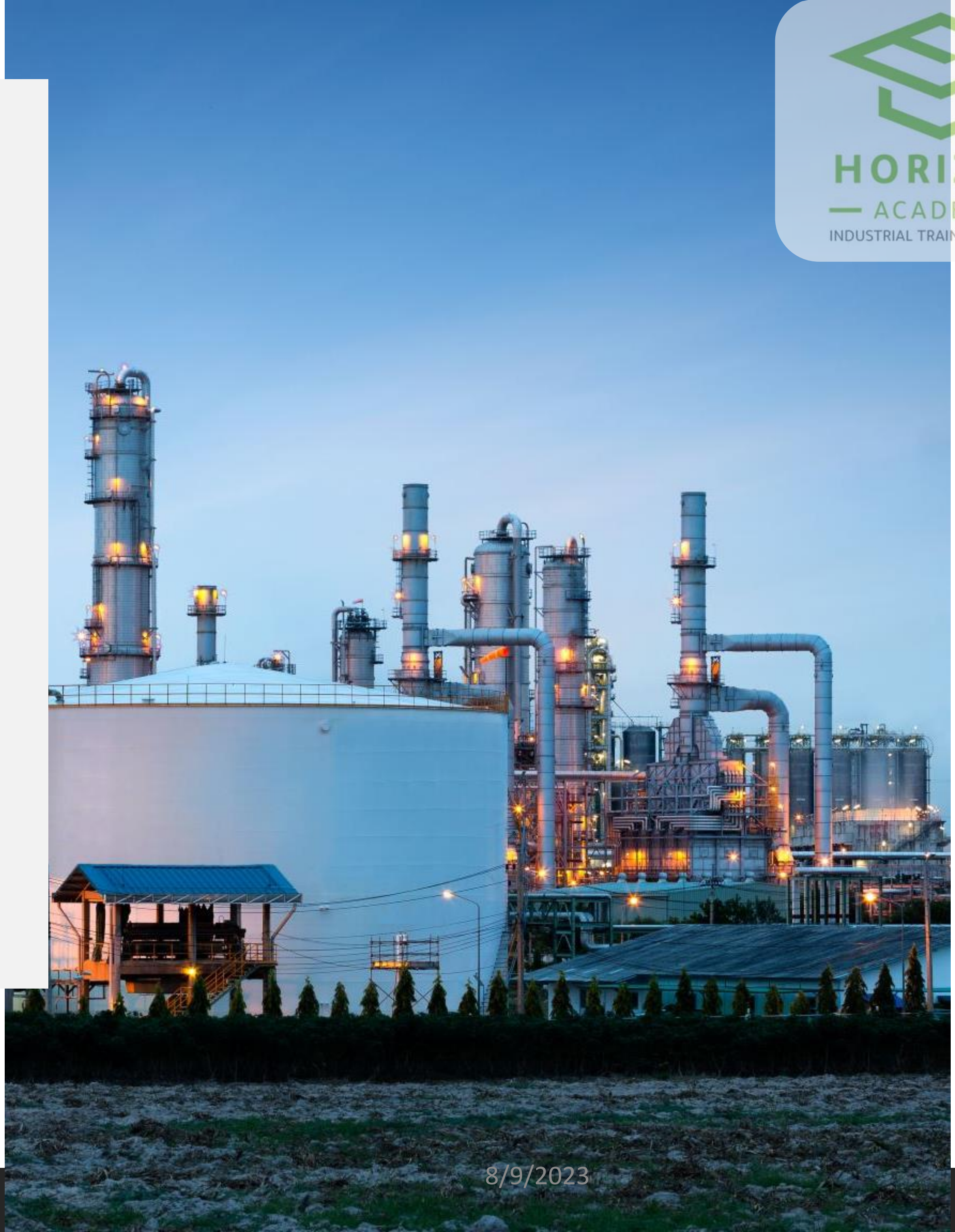
Content:

Types of cooling towers

Heat exchanger

Cooling water treatment

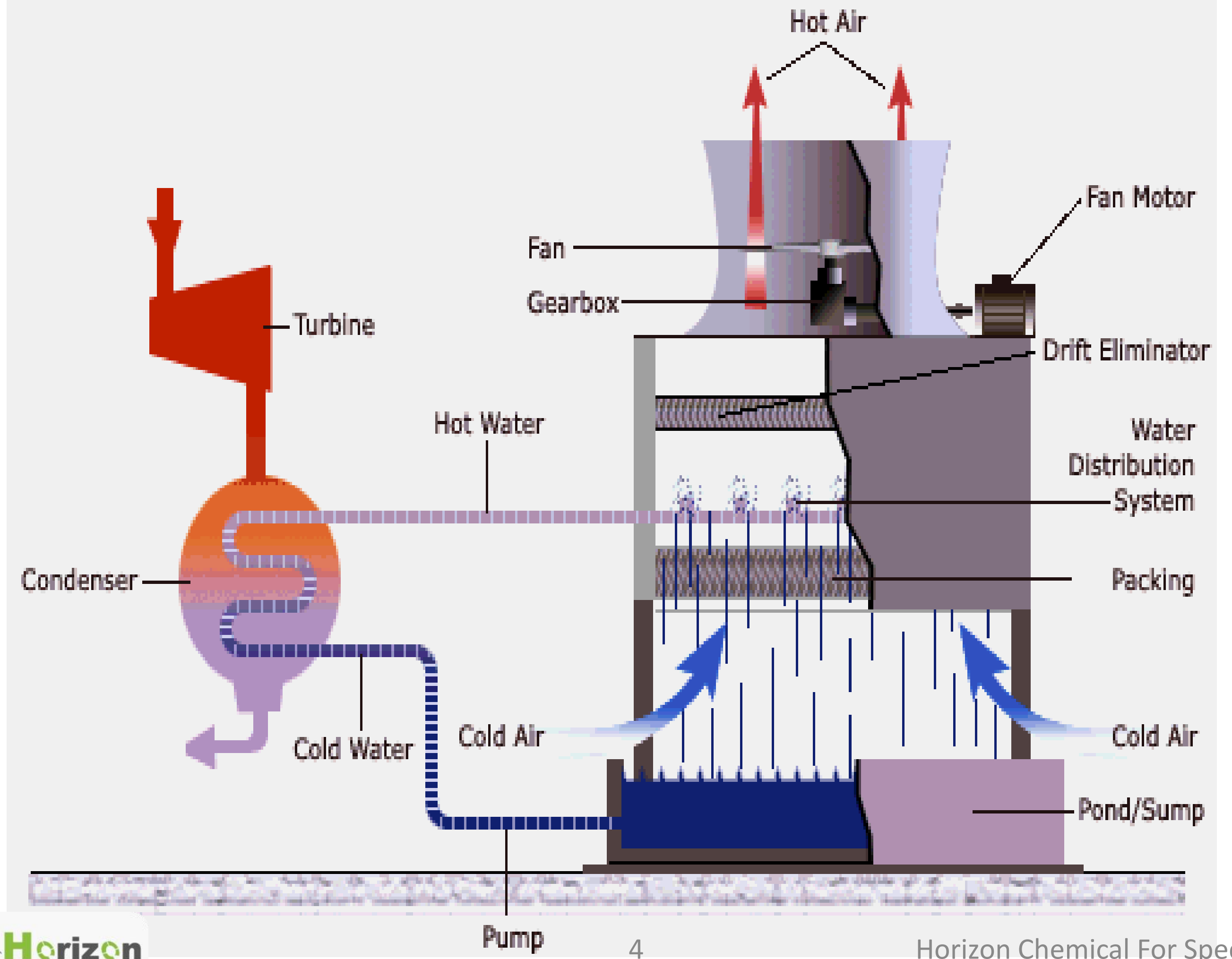
Cooling tower controller



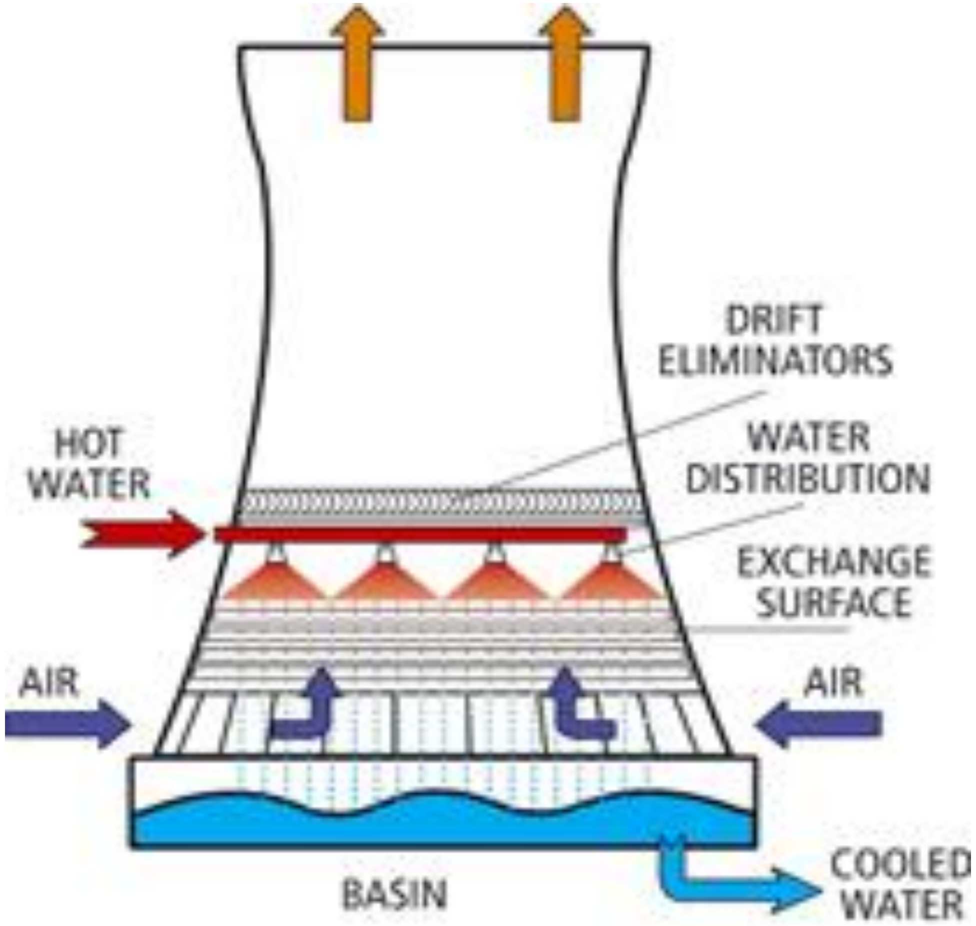
Cooling Towers

Types Of Cooling Towers

Induced Draft

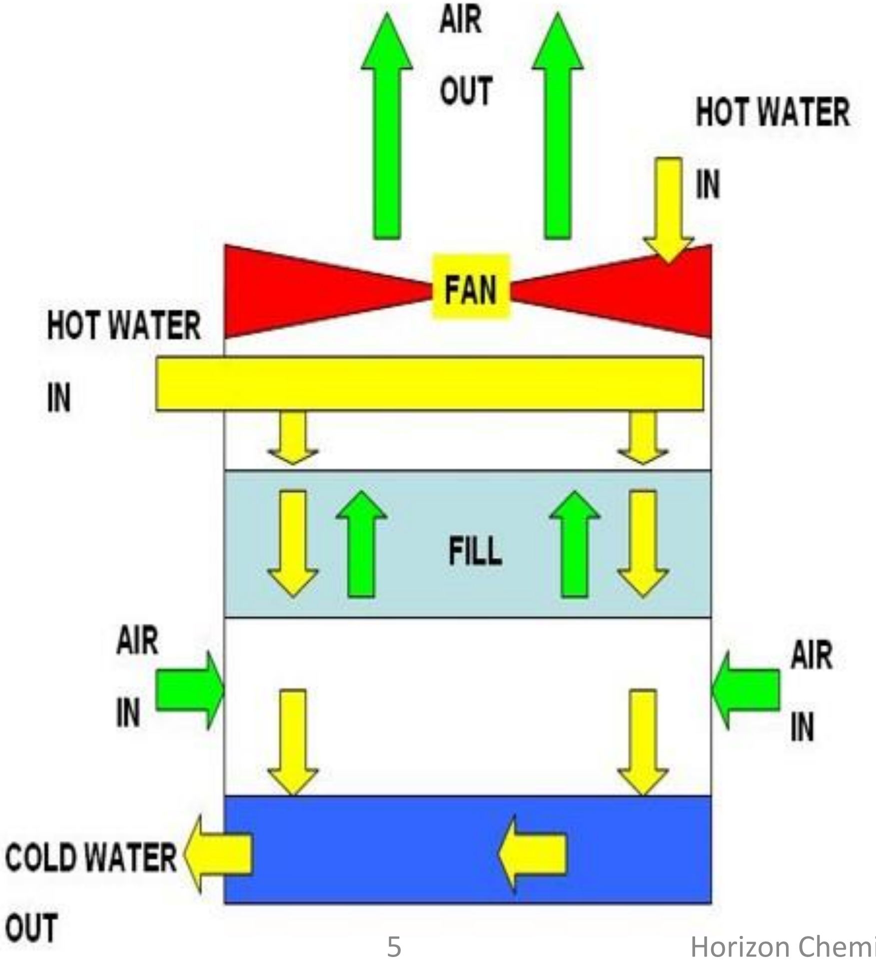


Natural Draft •

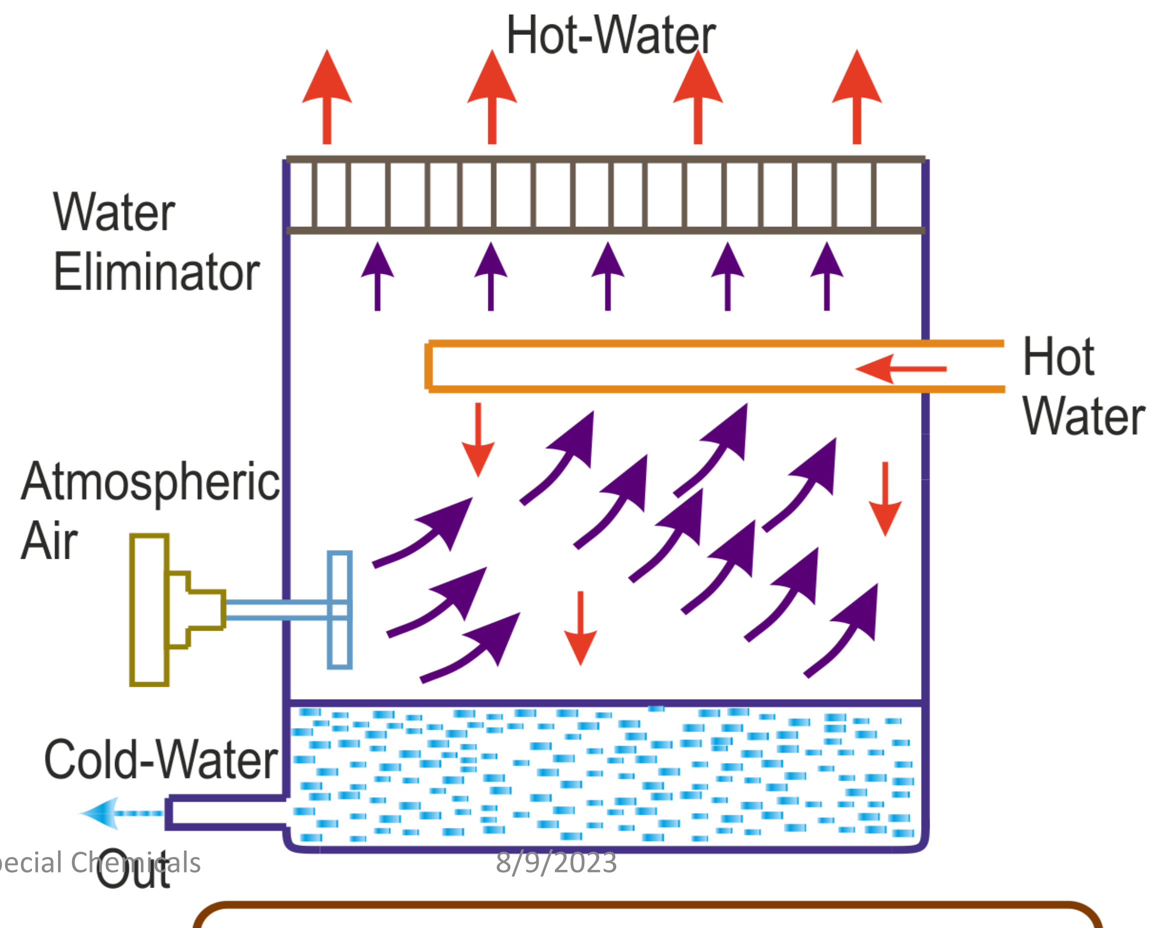


Non-natural draft

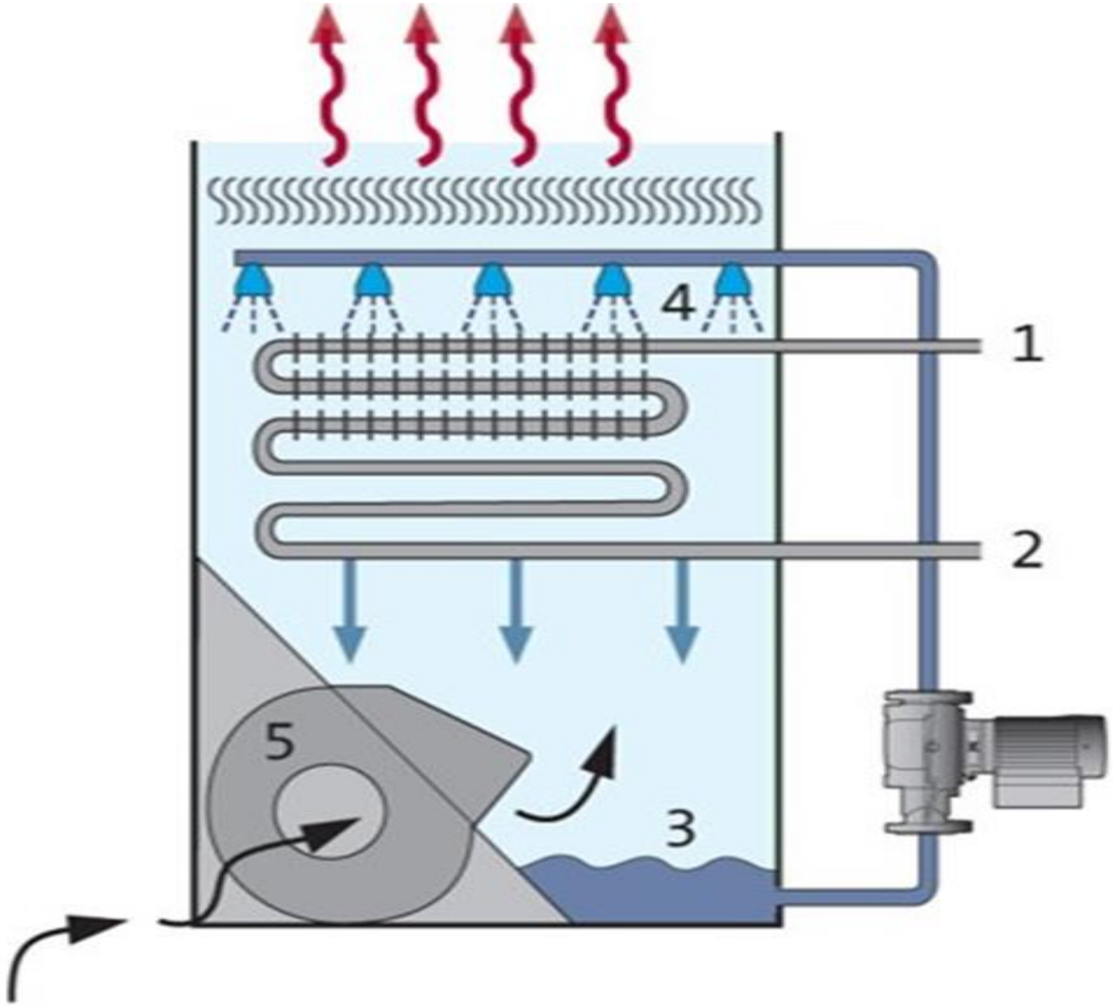
- **Induced draft**



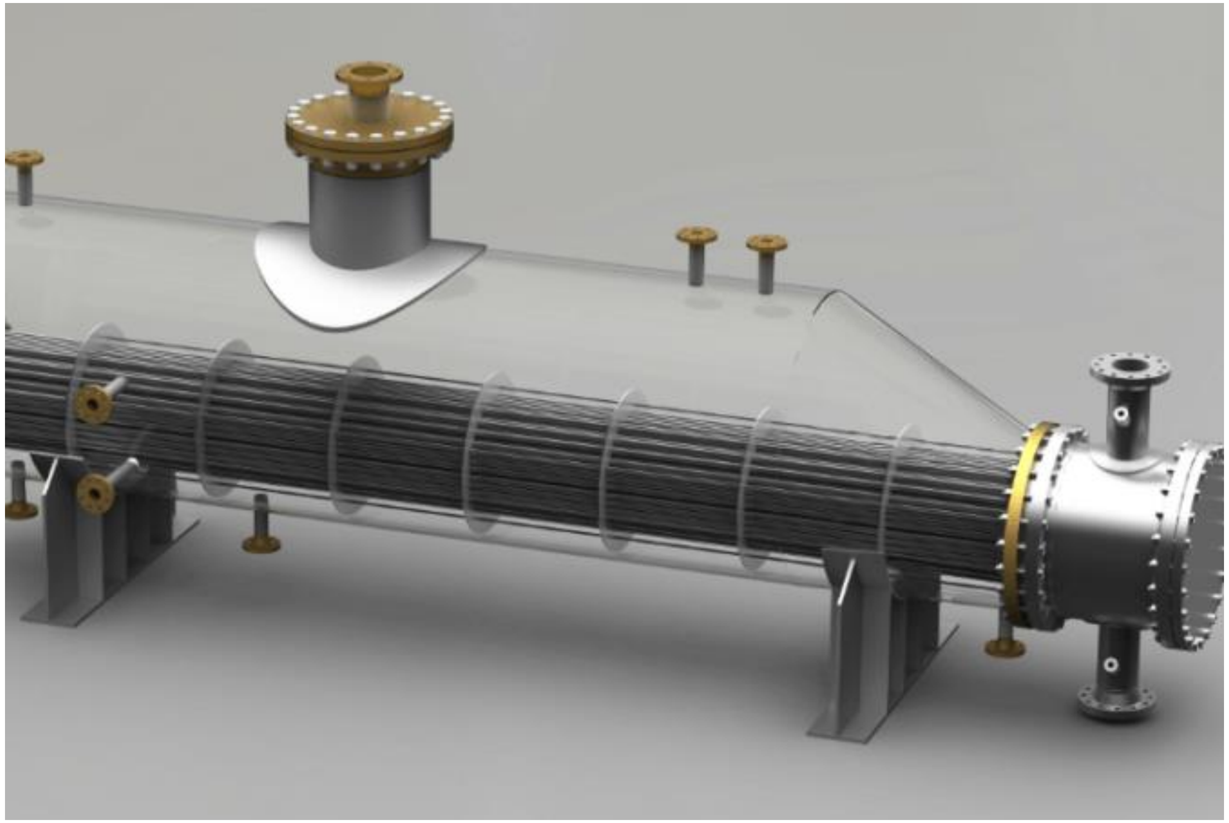
- **Forced draft**



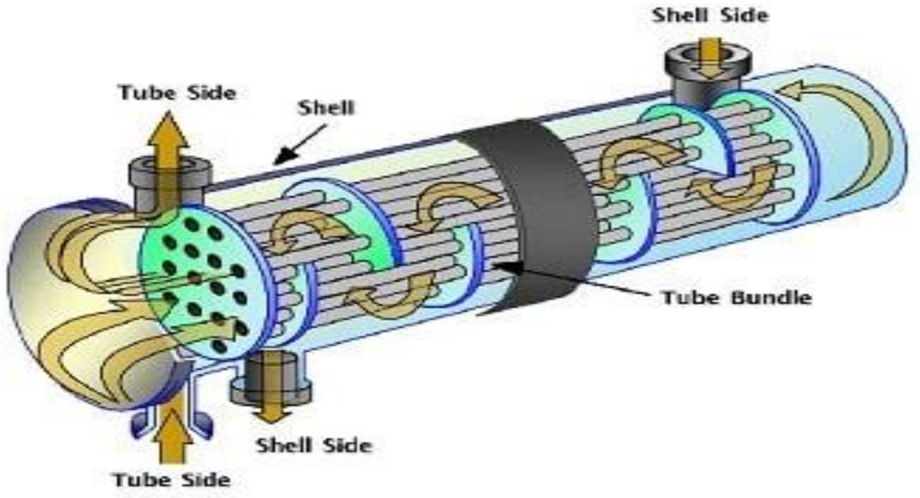
Evaporation Condenser



Heat Exchanger



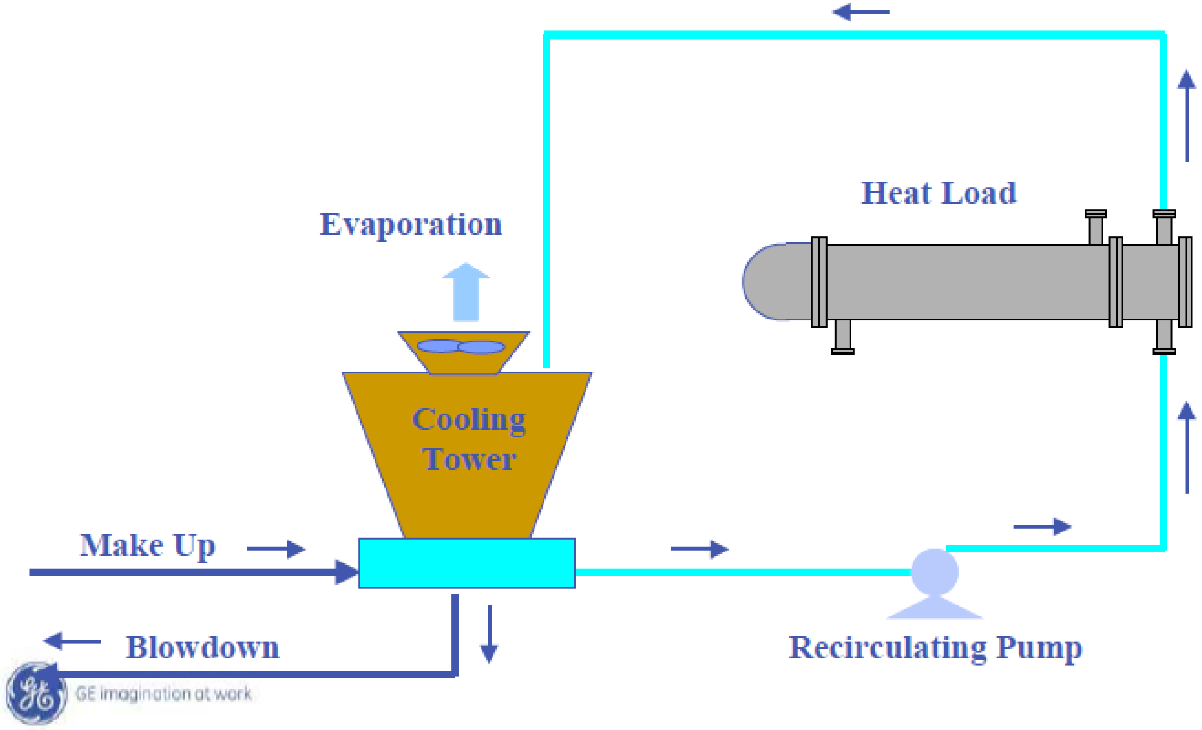
Heat exchanger



Shell & Tube

Plate

Cooling Water Treatment



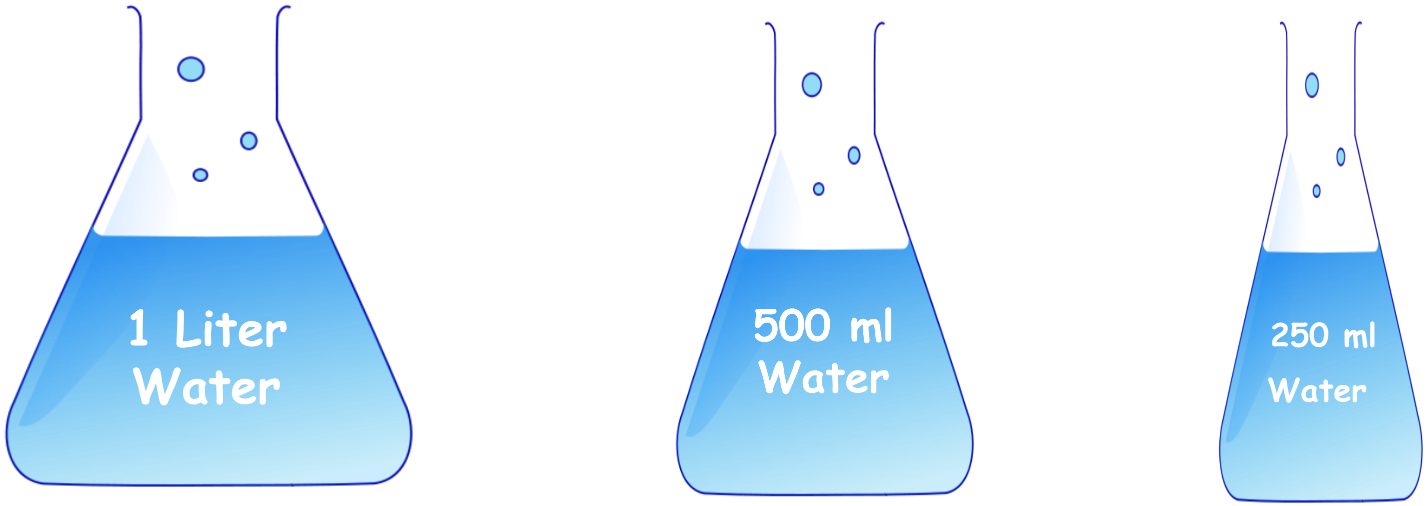
1. Scale
2. Corrosion
3. Fouling
4. Micro growth

1. Scale deposition

Due to the increase in the cycle Of concentration, the concentration of the dissolved ions in cooling water increases, and the solubility of one or more of the constituents is exceeded the solubility product. the compound precipitates and forms a deposit

Cycles of Concentration

If 5 grams salt are dissolved in each flask, then TDS is…



5 g Salt

TDS = 5,000 ppm

5 g Salt

TDS = 10,000 ppm

5 g Salt

TDS = 20,000 ppm

Scale treatment
(Adjust water chemistry –first defense line)
why shall we operate at high COC ?

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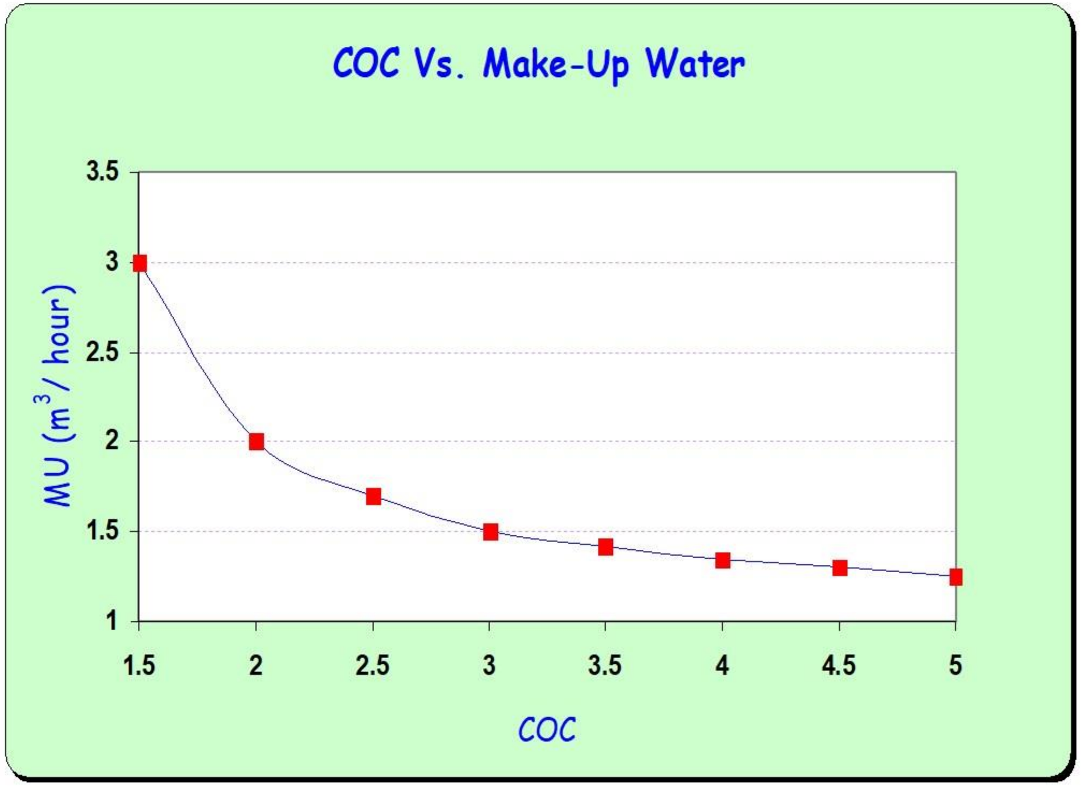
Makeup water volumes based on an Evaporation rate of 50,000 gal/day. (Bleed rate assumes no Windage loss)		
COC	Bleed (gal/day)	Makeup (gal/day)
2x	50,000	100,000
3x	25,000	75,000
4x	16,666	66,666
5x	12,500	62,500
6x	10,000	60,000
7x	8,333	58,333
8x	7,143	57,143
9x	6,250	56,250
10x	5,555	55,555



Scale treatment
(Adjust water chemistry –first defense line)
LANGELIER SATURATION INDEX

"Conditions at which a given water is in equilibrium with calcium carbonate".

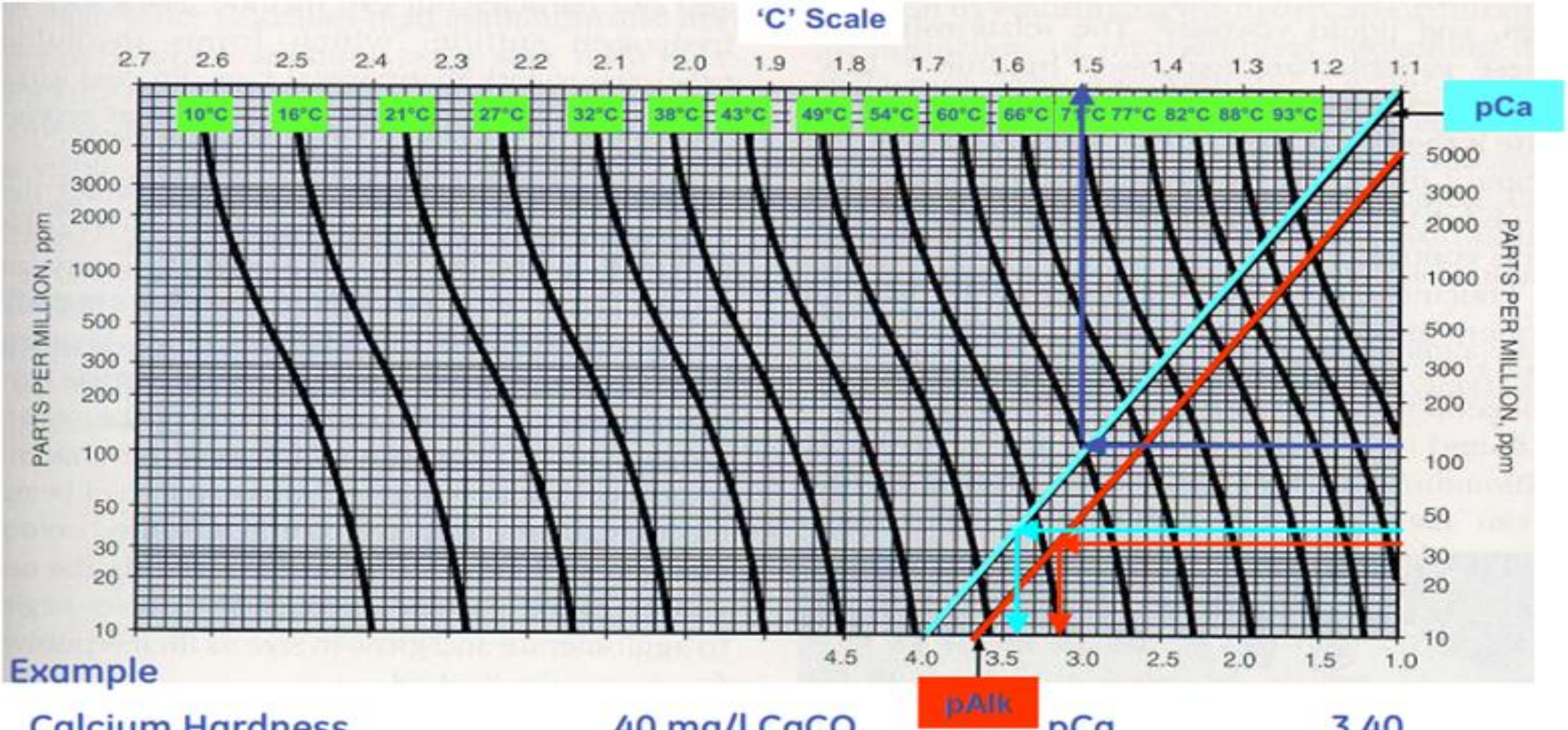
$$pHs = (pK_2 - pK_s) + pCa + pAlk$$

pK_2	= 2° dissociation constant of $CaCO_3$
pK_s	= solubility product of $CaCO_3$
pCa	= -log calcium concentration
$pAlk$	= -log alkalinity

$$LSI = pH_a - pH_s$$

LSI -ve : water tends to dissolve calcium carbonate and hence the water has corrosive tendency

LSI +ve : water has a calcium carbonate scaling tendency



Example

Calcium Hardness	40 mg/l $CaCO_3$	pCa	3.40
M Alkalinity	35 mg/l $CaCO_3$	pAlk	3.15
Total Dissolved Solids	120 mg/l		
Temperature	60 °C	"C" at 60 °C	1.50
pH of Cooling Water (pH_a)	7.10	Total (pH_s)	8.05

$LSI = pH_a - pH_s = -0.95$

Scale Treatment
(Adjust Water Chemistry –First Defense Line)
Ryznar Saturation Index(RSI)

Ryznar studied the actual operating results obtained with waters of various Saturation Indices

$$RSI = 2pH_s - pH_a$$

Ryznar Stability Index

> 7.5 or 8 probability of corrosion increases

> 7 scaling may not occur

< 6 scaling tendency increases, probability of corrosion decreases

RYZNAR STABILITY INDEX

$$RSI = 2pH_s - pH_a$$

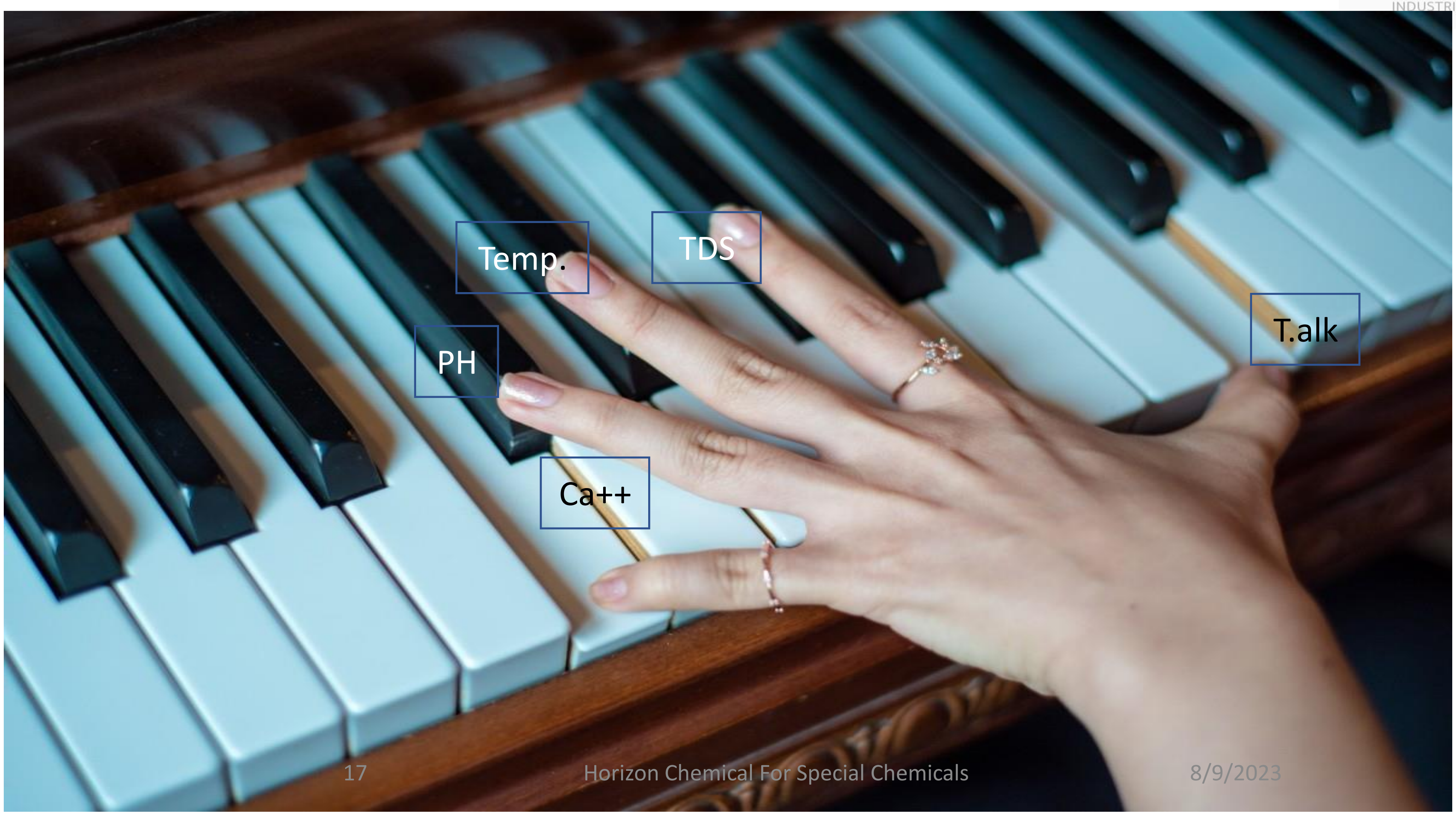
Ryznar Stability Index

> 7.5 or 8	probability of corrosion increases
> 7	scaling may not occur
< 6	scaling tendency increases probability of corrosion decreases

Examples:

Calcium Hardness	200 mg/l $CaCO_3$	pCa	2.70
M Alkalinity	160 mg/l $CaCO_3$	pAlk	2.50
Total Dissolved Solids	400 mg/l		
Temperature	60 °C	"C" at 60 °C	1.56
		Total (pH_s)	6.76
pH of Cooling Water (pH_a)	7.80	$LSI = pH_a - pH_s$	= +1.04 SCALING
		$RSI = 2pH_s - pH_a$	= 5.72 SCALING

Scale treatment
(Adjust water chemistry –first defense line)



Scale treatment
(chemical treatment –second defense line)

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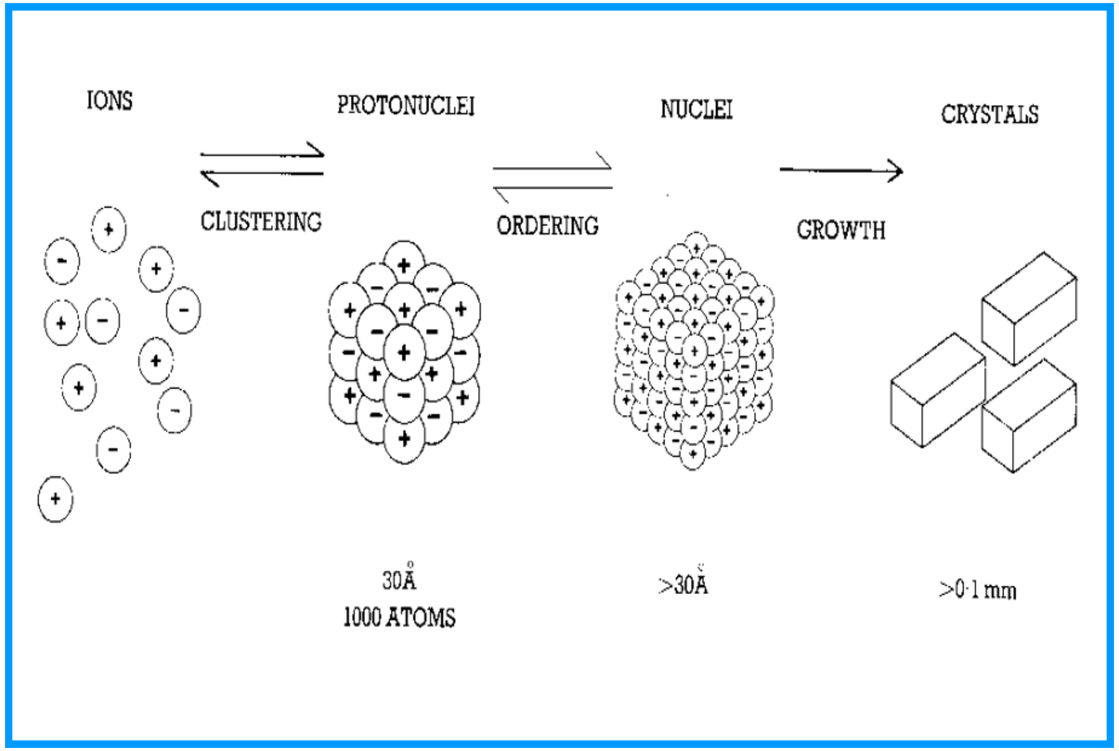
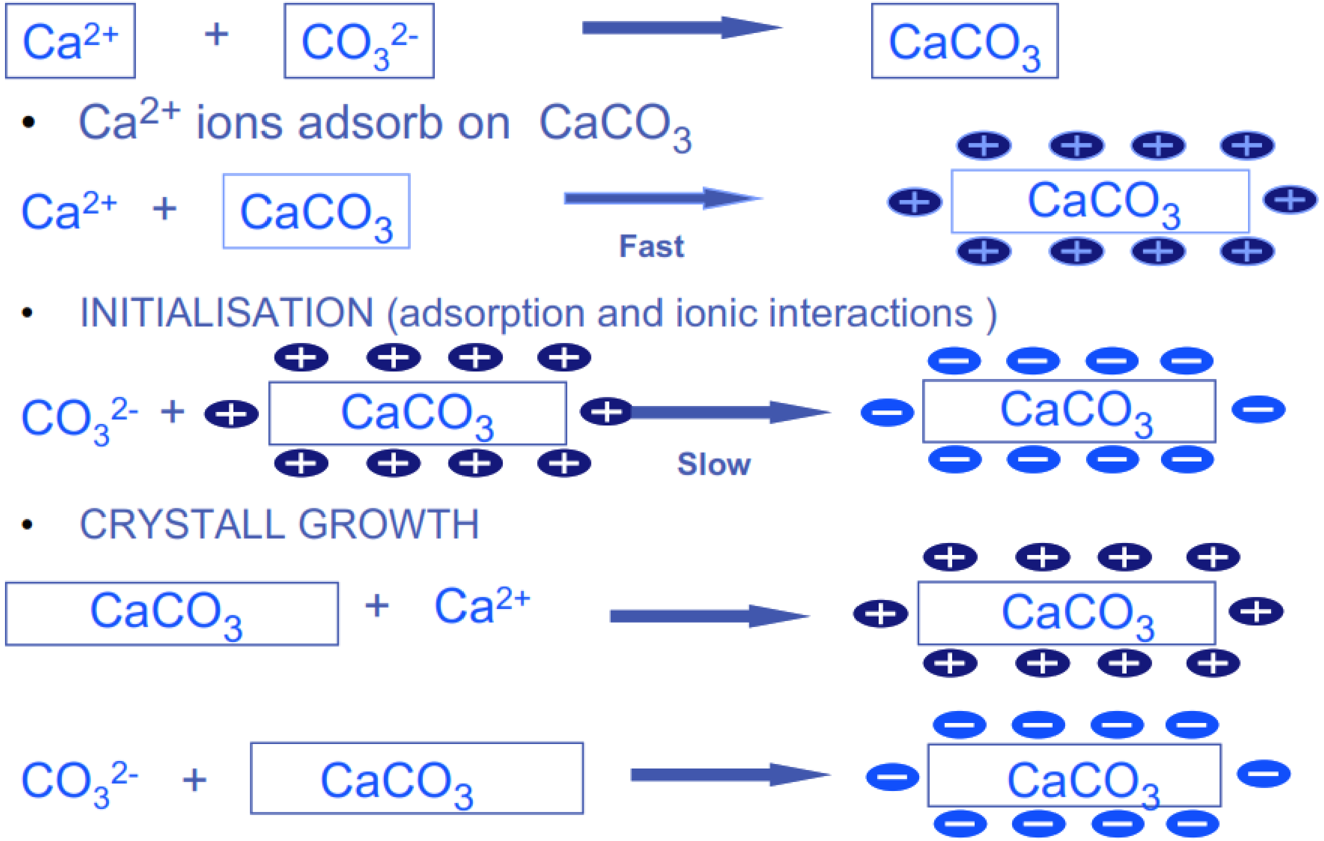
$CaCO_3$ SCALE INHIBITION CHEMISTRIES

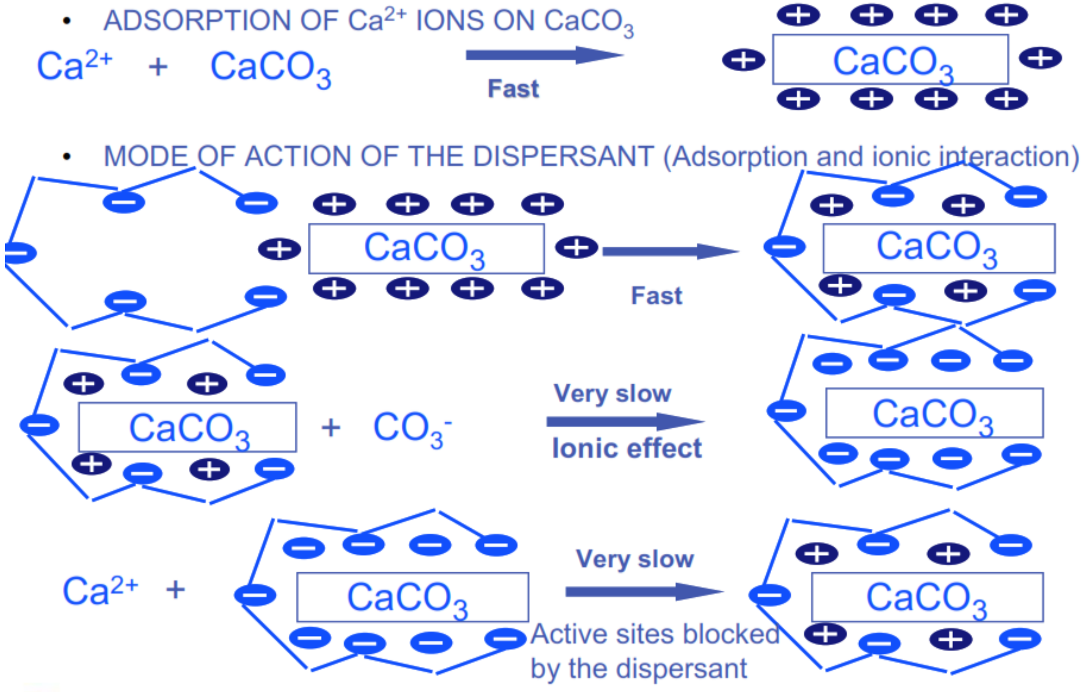
- INHIBITION
  - CHELATING (COMPLEXING) ← EDTA
  - ADSORPTION ← PHOSPHONATES
  - CRYSTALL GROWTH INHIBITION ← AEC
  - DECREASE OF CRYSTALL GROWTH CYNETICS ← TETRAPHOSPHONATES
  - DISTORSION OF THE CRYSTALL ← TETRAPHOSPHONATES, POLYACRYLATES
  - DISPERSION OF PARTICLES ← POLYACRYLATES
- DISPERSION

POLYACRYLATES
POLYCARBOXYLATES
POLYMALEATES



Scale treatment
(chemical treatment –second defense line)





Scale treatment
(chemical treatment –second defense line)

Polyphosphates

Sensitive to hydrolysis (into oPO4) depending on :

temperature (50 - 60°C)

residence time

pH in the system

Phosphonates

Chelating effect

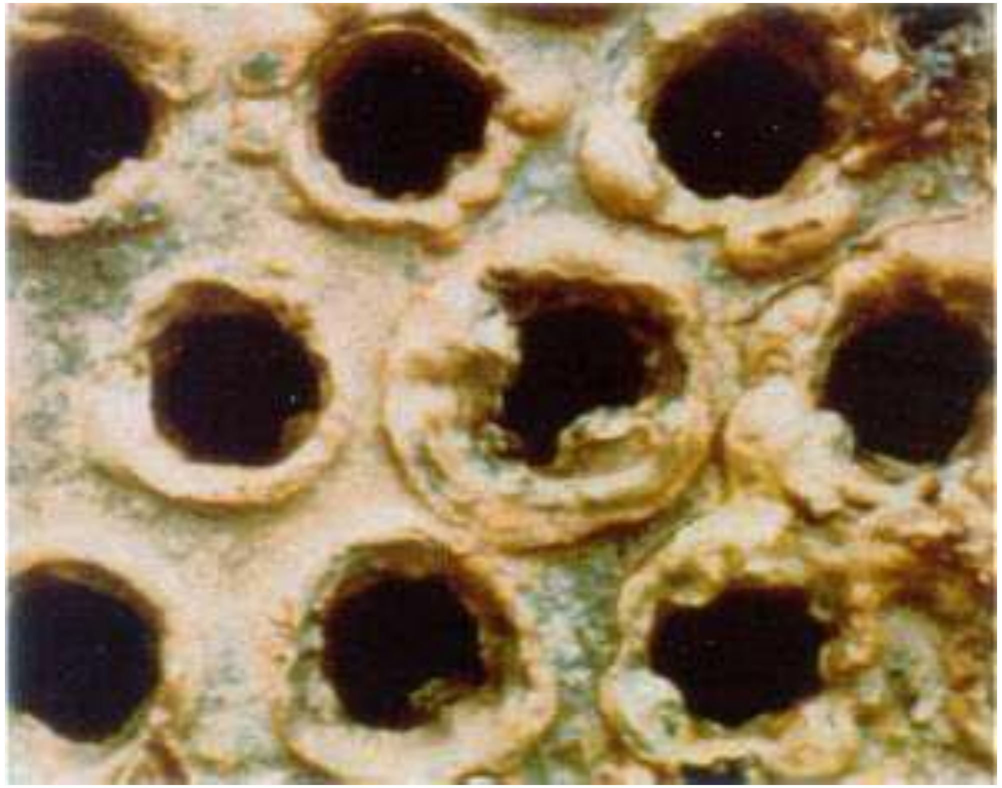
Blocks the generation of $CaCO_3$ crystals

Reduce speed of growth

Depending on the type of phosphonate

Sensitivity to chlorination (oxidation)

Little to no risk of Ca phosphonate precipitation

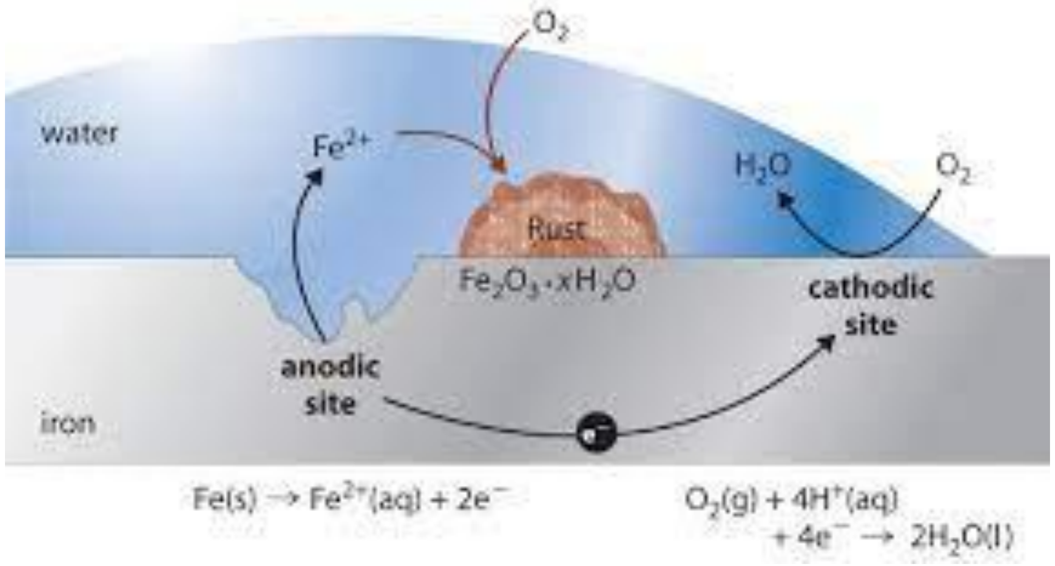


Scale treatment
(chemical treatment –second defense line)

Polyacrylates

Polymethacrylates

2. Corrosion



$$Fe \rightarrow Fe^{2+} + 2\,e^{-} \text{ (Anodic)}$$

$$2\,H_2O + O_2 + 4\,e^{-} \rightarrow 4\,OH^{-} \text{ (Cathodic)}$$

$$Fe^{2+} + 2\,OH^{-} \rightarrow Fe(OH)_2 \text{ (Chemical)}$$

Corrosion in cooling towers

- There are many reasons for corrosion , and here are some of them
- Scales (under deposit corrosion)
- Erosion
- Micro growth
- Low lsi
- Absence of anodic and /or cathodic inhibitors
- Higher conc. Of aggressive anions (So4 , cl-)

(chemical treatment –second defense line) Classification of corrosion inhibitors

Table 3.9 Classification of corrosion inhibitors

Type of corrosion inhibitor		Example of corrosion inhibitor	Characteristics of protective film
Oxide film type (passivation film type)		Chromates, Nitrites, Molybdates	Fine and thin film (30–200Å), closely adherence to metal, excellent corrosion protection
Precipitation film type	Chemicals forming the insoluble salts with calcium ions, etc., in water	Polyphosphates, Orthophosphates, Phosphonates, Zinc salts	Relatively porous and relatively thick film, slightly poor adherence to metal, fairly good corrosion protection
	Chemicals forming water insoluble salts with the protected metal ion	Mercaptobenzothiazole, Benzotriazole, Tolyltriazole	Relatively close and relatively thin film, fairly good corrosion protection
Adsorption film type		Amines, Surfactants	Formation of perfect adsorption layer on clean metal surface in acid or non-aqueous solution and formation of non-uniform adsorption layer on unclean surface in fresh water

Cathodic Inhibitors (Precipitating film)

- They can either:
  - Slow down the rate of cathodic reactions.
  - Selectively precipitate on cathodic areas to impede or limit diffusion of reducible species (H_2, O_2) to these areas.

- Applied Mechanisms:

1. Cathodic Poisoning: compounds of Arsenic (As) and Antimony (Sb) make the recombination and discharge of hydrogen make difficult.
2. Precipitation: Calcium, Zinc, and Magnesium Oxides precipitate to form protective films on the cathode.

Anodic (Passivating) Inhibitors

- They cause a large anodic "shift" of the corrosion potential forcing the metal surface to the "passivation range".
- Two main types are known:

1) Oxidizing anions: such as Chromate, Nitrate, and Nitrite. They can passivate steel in the absence of oxygen.

2) Nonoxidizing ions: such as Molybdate, Phosphate, and Tungstate. They passivate steel in the presence of Oxygen.

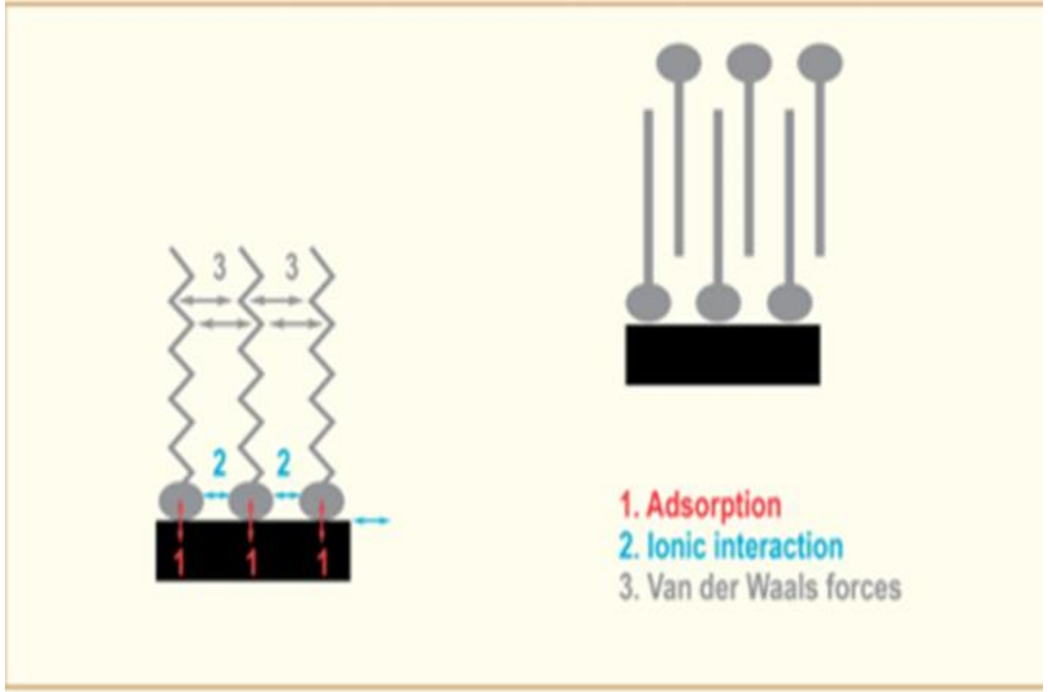
- Most effective and very widely used.

- Less Expensive.

Adsorption film (film forming)

- They effect the entire surface of corroding metal in equal concentration.
- Film-forming: They form a hydrophobic film on metal surface which provides a barrier to dissolution of metal in the electrolyte.
- Adsorbed on surfaces depending on their charge and surface charge.
- Can be Cationic (Amines) or Anionic as (Sulfonates).
- Example…

\- Ethanol amine (used to stop Ethylene glycol corrosion in cooling systems).



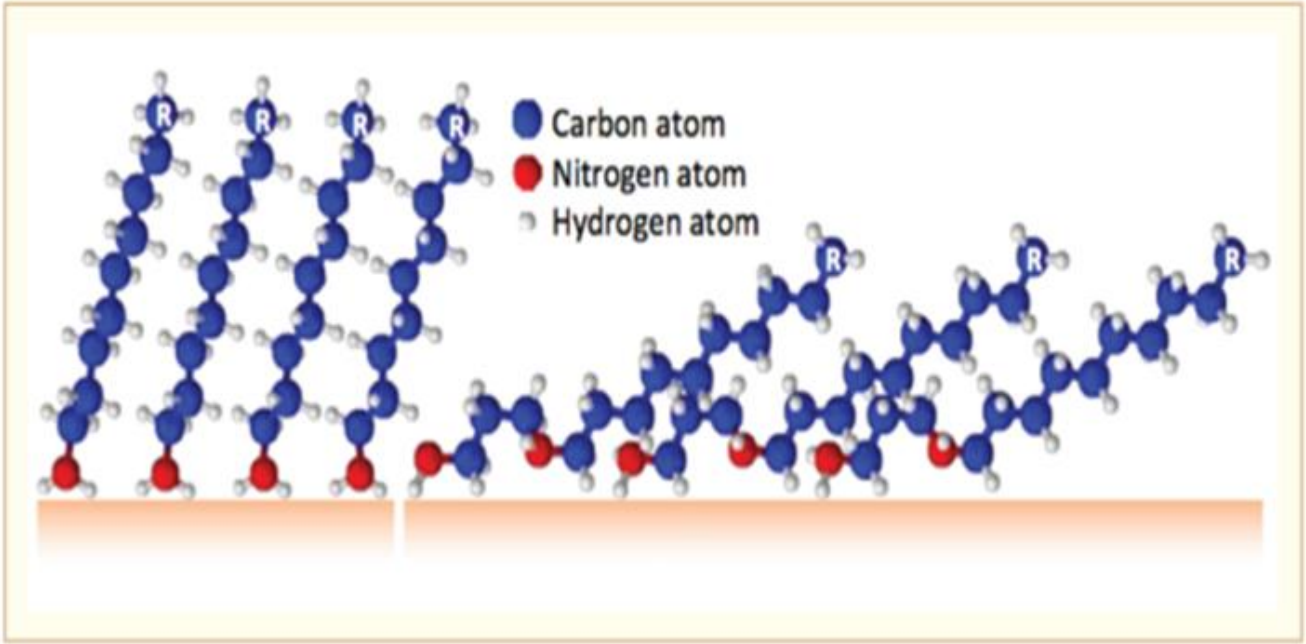


Figure 3-2: Schematic representations of FFA films: monoamine (left), polyamine (right) [Jack et al., 2015]

General Effect - Precipitation Inhibitors

- Film forming: they block both anodic and cathodic sites “indirectly”.
- They cause the formation of precipitates leading to the formation of protective film.
- Depend much on the hardness value in water (high hardness is less corrosive because of more salt tendency to precipitate).
- High pH dependence.
- Common inhibitors are Silicates and Phosphates.
- Sodium silicate is used in domestic waters to prevent “rust water”.
- Phosphates require oxygen for effective inhibition.

Classification of Corrosion Inhibitors second defense line

Most Widely Classified as: -

1)Cathodic (Precipitating film)

- $CaCO_3$
- $Ca_3(PO_4)_2$
- POLY PO4
- ZINC

and Azoles

2)Anodic (Passivating).

- CrO_4^{2-}
- MoO_4^{2-} hc
- NO_2^-
- PO_4^{3-} hc
- Na_3SiO_4
- Poly PO_4 hc

3)Adsorption film (film forming) poly amine

Corrosion

Pitting

Tubercule

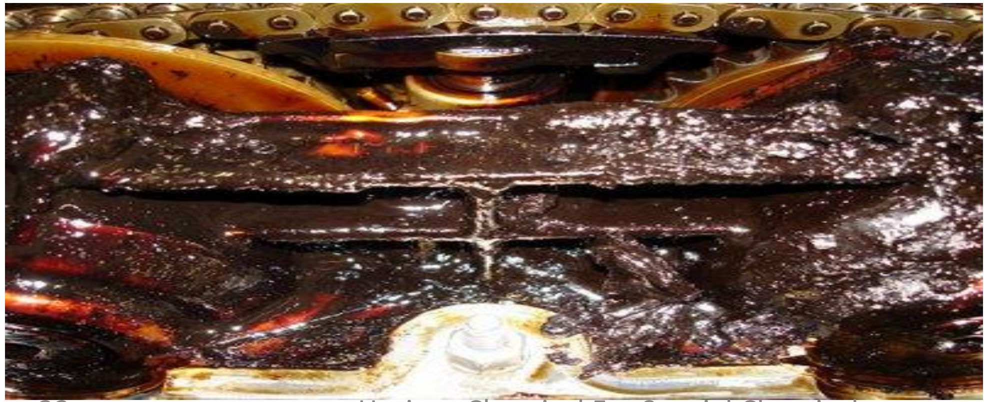
Microbiological Control

- Active action

- Sulfate reducing bacteria
- Nitrifying bacteria
- De-nitrifying bacteria
- Iron reducing Bacteria

- Passive action

- Slime forming
- Algae colonies
- bio film



Microbiological Control
(chemical treatment –second defense line)

- Oxidizing Biocides
- "Indiscriminate oxidation"
  - non-specific
  - react also with suspended solids and organic matter
  - halogenated by-products may be formed

- Non-Oxidizing Biocides
- Specific Reactions
  - specific mode of action
  - organisms may acclimatize to the biocide
  - more expensive

Microbiological Control (chemical treatment –second defense line)

- Oxidizing Biocides
- “Indiscriminate oxidation”
  - Chlorine gas
  - Sodium hypochlorite
  - Calcium hypochlorite
  - Chlorine dioxide
  - Solid halogen donors
  - Activated Bromide
  - Peracetic Acid
  - Ozone

- Non-Oxidizing Biocides
  - Specific Reactions

Dbnpa

Bronopol

Quaternary Ammonium Salts

Glutaraldehyde

Iso-thiazolinone

Triazines

Blends

Oxidizing Biocides & pH Effect

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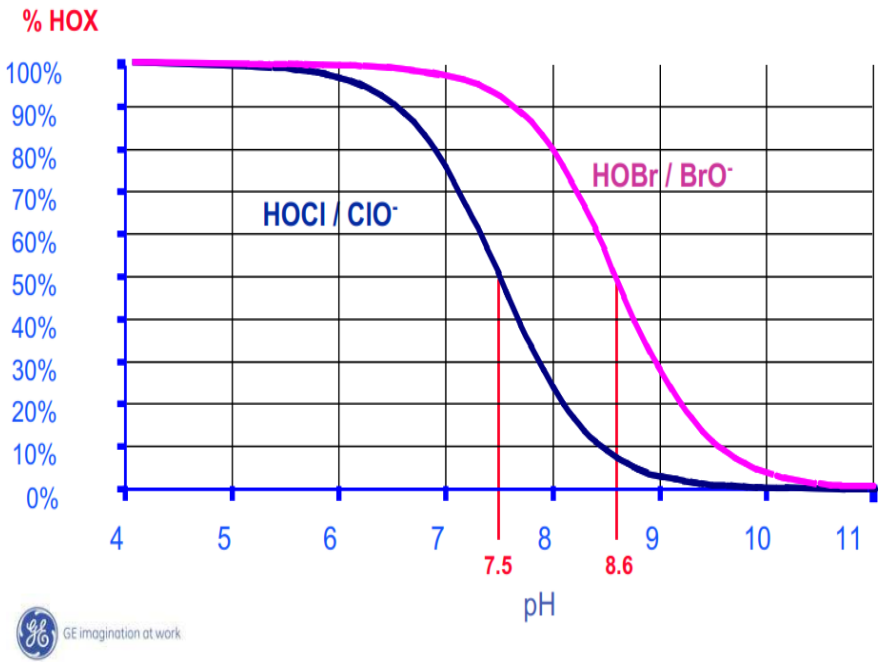
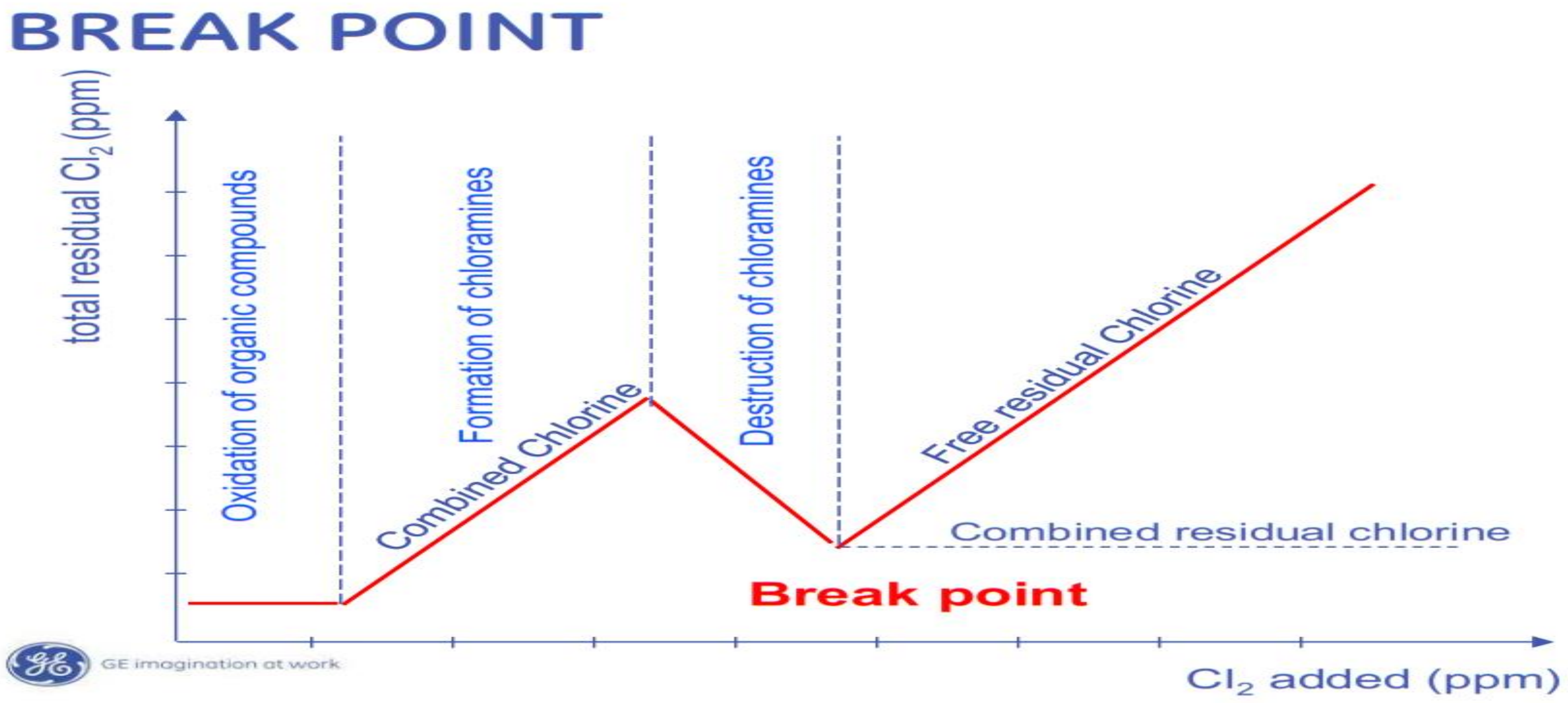
$HOCl \rightleftarrows H^+ + OCl^-$ (Hypochlorite ion, less effective)

$HOBr \rightleftarrows H^+ + OBr^-$ (Hypobromite ion, less effective)

	pH value in Cooling Water					
	6.0	7.0	7.5	8.0	8.5	9.0
% Available HOCl	97	76	50	24	9	3
% Available HOBr	100	98	94	83	60	33



Chlorine dosing (break point)



3.Fouling

Definition: fouling is the accumulation of unwanted material on solid surfaces, most often in aquatic environment.

Fouling occurs on a surface of a component, system or plant performing a useful function causing disturbance or interference with this function.

Types:

1- Colloidal.
2- Biofouling.
3- Organic.
4- Scaling.

Fouling
first defense line

- Dispersant polymers (polyphosphates, polyacrylates…etc)..
- Side-stream sand filtration.
- Polyelectrolytic precipitation (Coagulants and Flocculants).

The Main Problems In Water

- Water is the strongest solvent on the earth

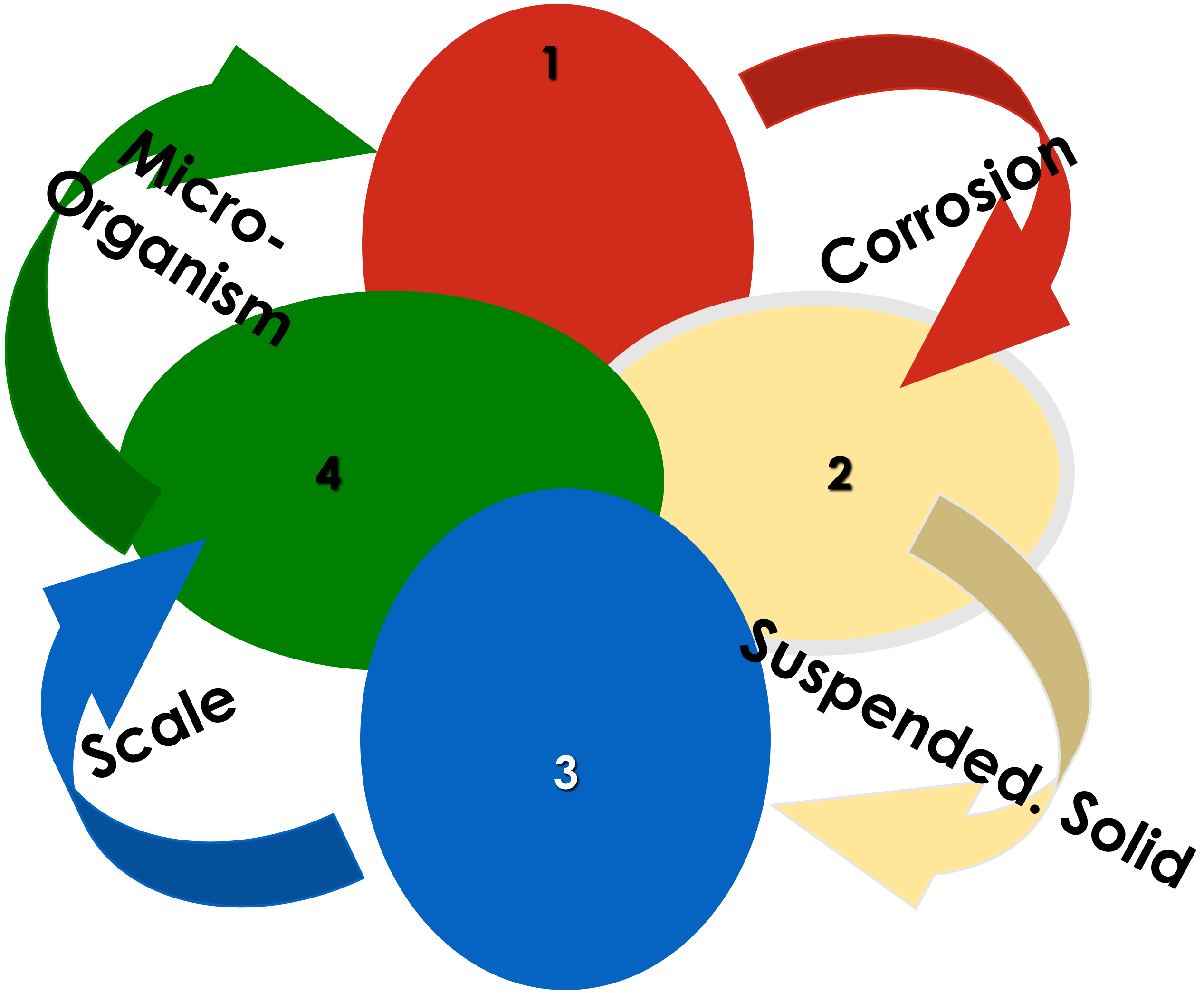
we find in water:

(1) suspended solids

(2) dissolved solids

(3) dissolved gases

all these components dissolved in water cause problems in the operation of boilers, which must be addressed



Cooling tower controller

Why cooling tower controller ?

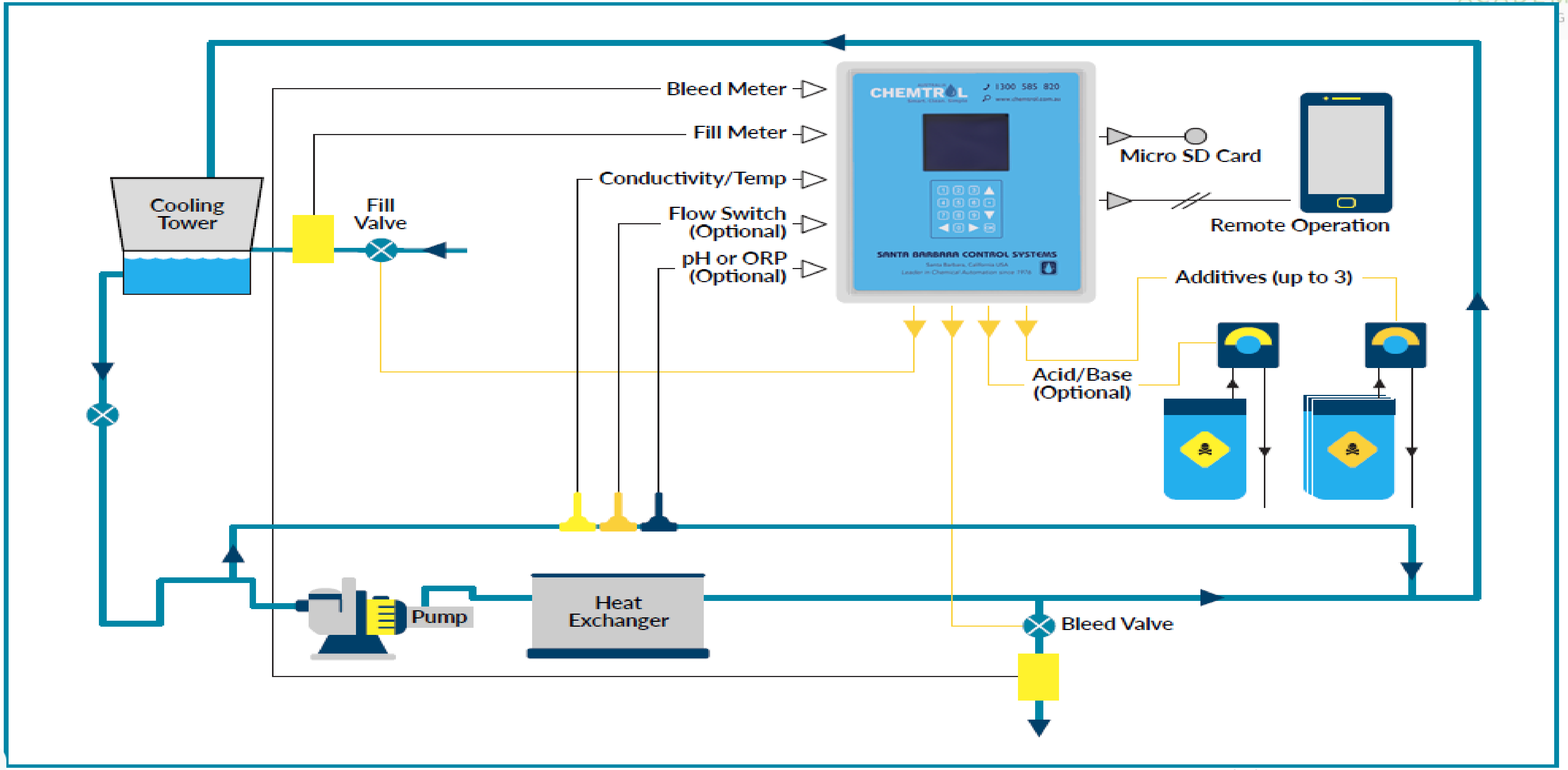
Definition :

- a cooling tower controller is used to automate the chemical feed of your corrosion and scale prevention chemical and biocide.
- it also controls the (conductivity blowdown set points-adjust PH and chlorine injection) to maximize water reuse and to ensure a successful water treatment program.

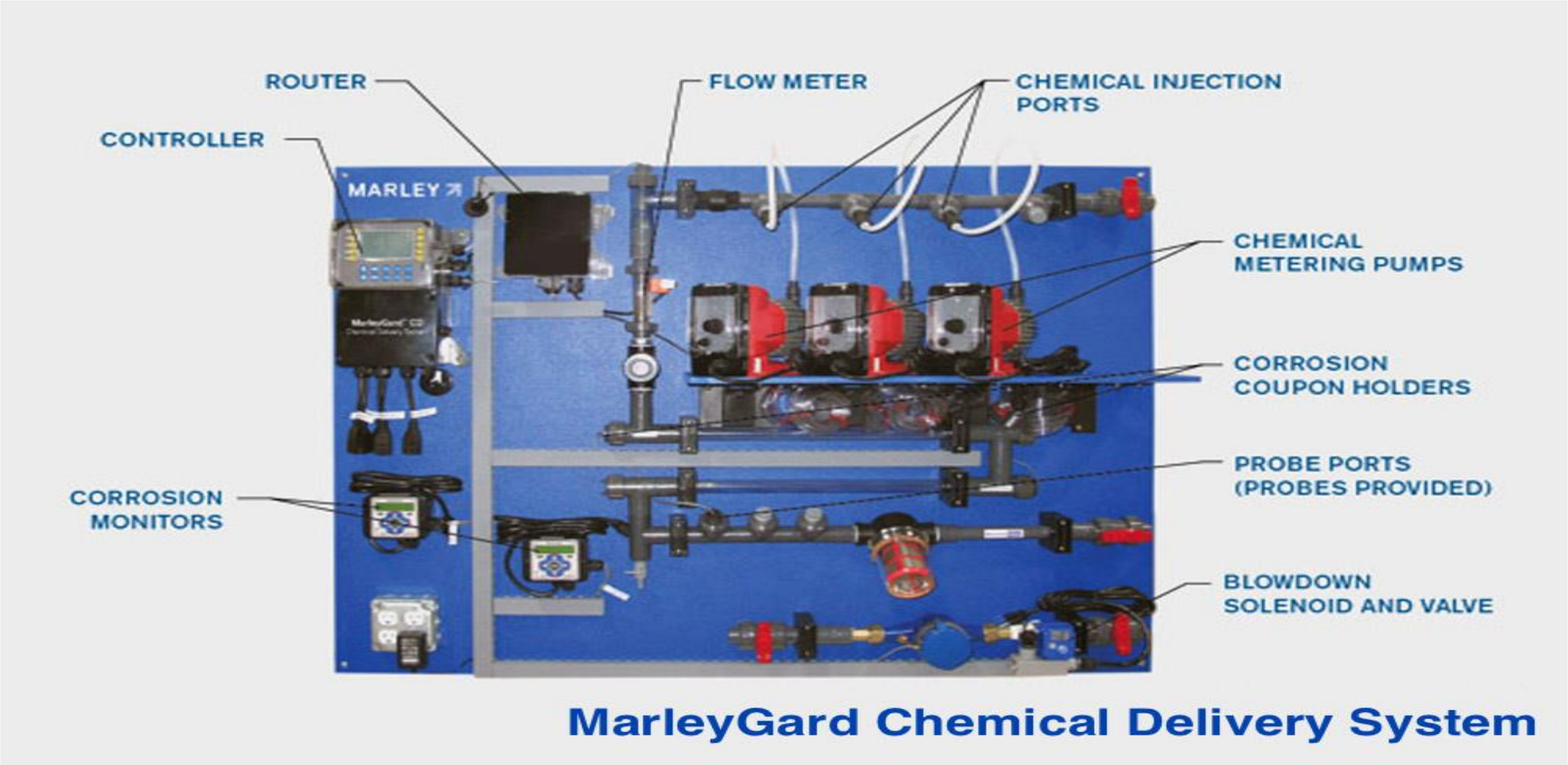
Why controller?

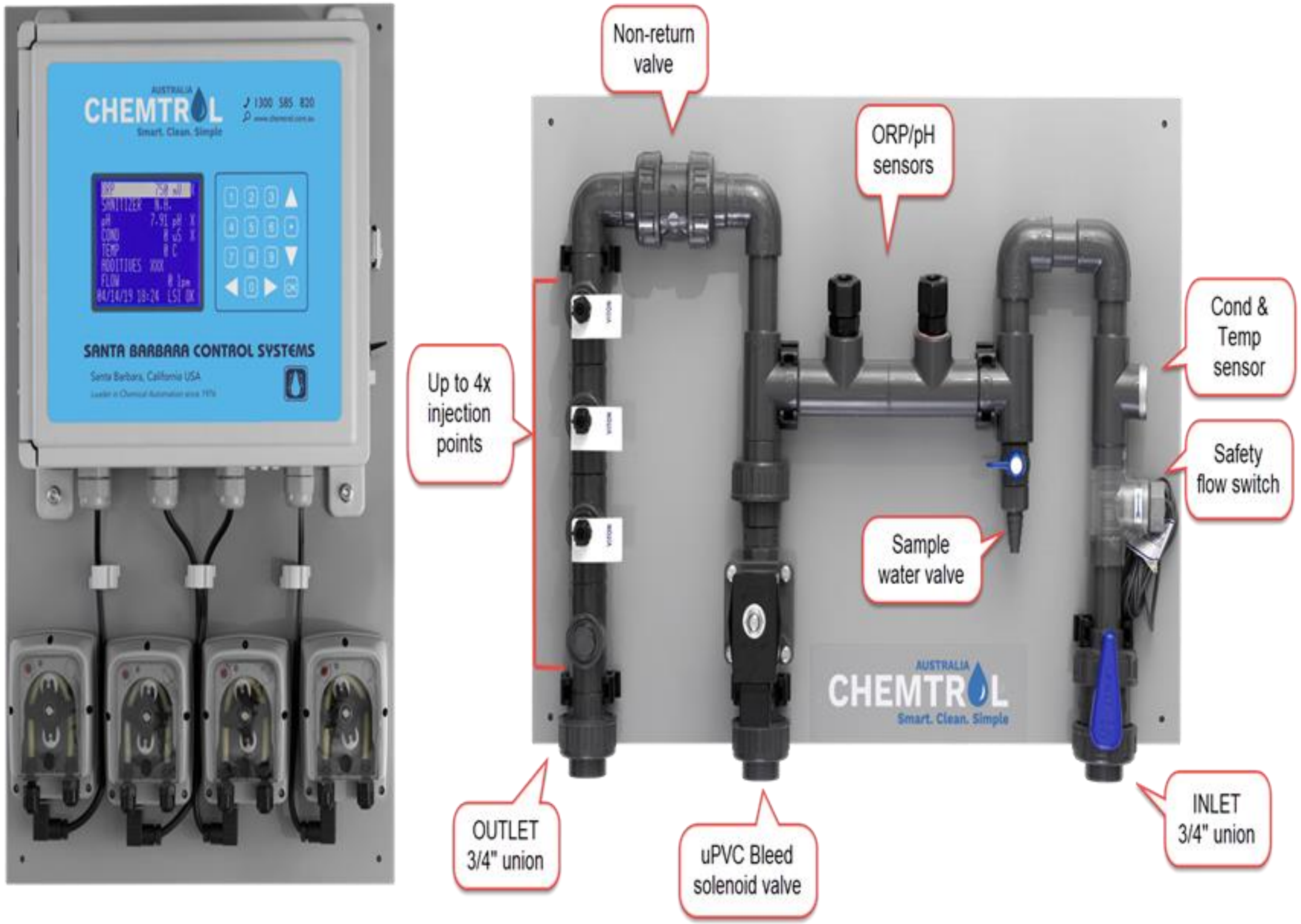
- Avoid water waste
- Avoid chemical waste
- Improve system performance
- Minimize corrosion, scaling, and micro growth problems
- Record and trace operational problems
- Easy way for reporting water treatment parameters
- Labor reduction , eliminating failure due to human factor

Cooling tower controller



Cooling tower controller (Rac component)




CHEMTROL
Smart. Clean. Simple
SANTA BARBARA CONTROL SYSTEMS
Santa Barbara, California USA
Non-return valve
ORP/pH sensors
Cond & Temp sensor
Up to 4x injection points
Safety flow switch
Sample water valve
OUTLET 3/4" union
uPVC Bleed solenoid valve
INLET 3/4" union

Cooling tower controller input

Input
- Water meter
- Chemical levels

Conductivity or induced conductivity
- Standby
- Flow
- conductivity probe
- Temperature probe

PH
- Stand by
- Flow
- PH level
- PH probe
- Temperature probe

ORP Or free chlorine
- Stand by
- Flow
- ORP level
- ORP probe
- Temperature probe

Corrosion
- Stand by
- Flow
- PH level
- PH probe
- Temperature probe

Tracer
- Stand by
- Flow
- TRC level
- TRC probe
- Temperature probe

MA 0-20 mA input
- Stand by
- Flow
- level
- Temperature probe

Cooling tower controller input

Conductivity or induced conductivity

PH

ORP

Or

free chlorine

Corrosion

Tracer

input

Cooling tower controller in put VS out put

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Conductivity or induced conductivity

Bleed

alarm

PH

Propotional

PH dosing system

alarm

ORP

Or

free chlorine

Proportional

ORP dosing system

alarm

Corrosion

Corrosion inhibitor dosing system

alarm

Tracer

TRC dosing system

alarm

Communication” remote management system ”

INSTRUMENT CONFIGURATION	PLUS	WHEN	REQUIREMENTS	FUNCTION
USB	USB output	You do not need a PC on your plant: you can download data log on a USB device	/	**RS485 output to link other EMEC instruments Data Log on USB device**
ETHERNET	LAN network between instrument and web	Remote control via WEB ERMES	LAN wiring (RJ-45)	**RS485 output to link other EMEC instruments Web ERMES remote control (PC, smartphone or tablet) Alarm messages via email**
MODBUS	**Connection to other devices (PLC) via RS485**	**PLC plant management**	**/**	**PLC connection output for reading and modifying parameters**

GSM/GPRS 1	3G/4G modem between instrument and web	Remote control via WEB ERMES	Network coverage	RS485 output to link other EMEC instruments Web ERMES remote control (PC, smartphone or tablet) Alarm messages via email Alarm messages via SMS
WIFI 1	WIFI network between instrument and web	Remote control via WEB ERMES	Network coverage	RS485 output to link other EMEC instruments Web ERMES remote control (PC, smartphone or tablet) Alarm messages via email

Brain storming

Could you treat cooling tower without using chemicals ??