GE Infrastructure
Water & Process Technologies

COOLING WATER TREATMENT

Advanced training course

Cairo– NOV , 2007

Shereif Alsayed
Cooling Water *Support Leader MEA*

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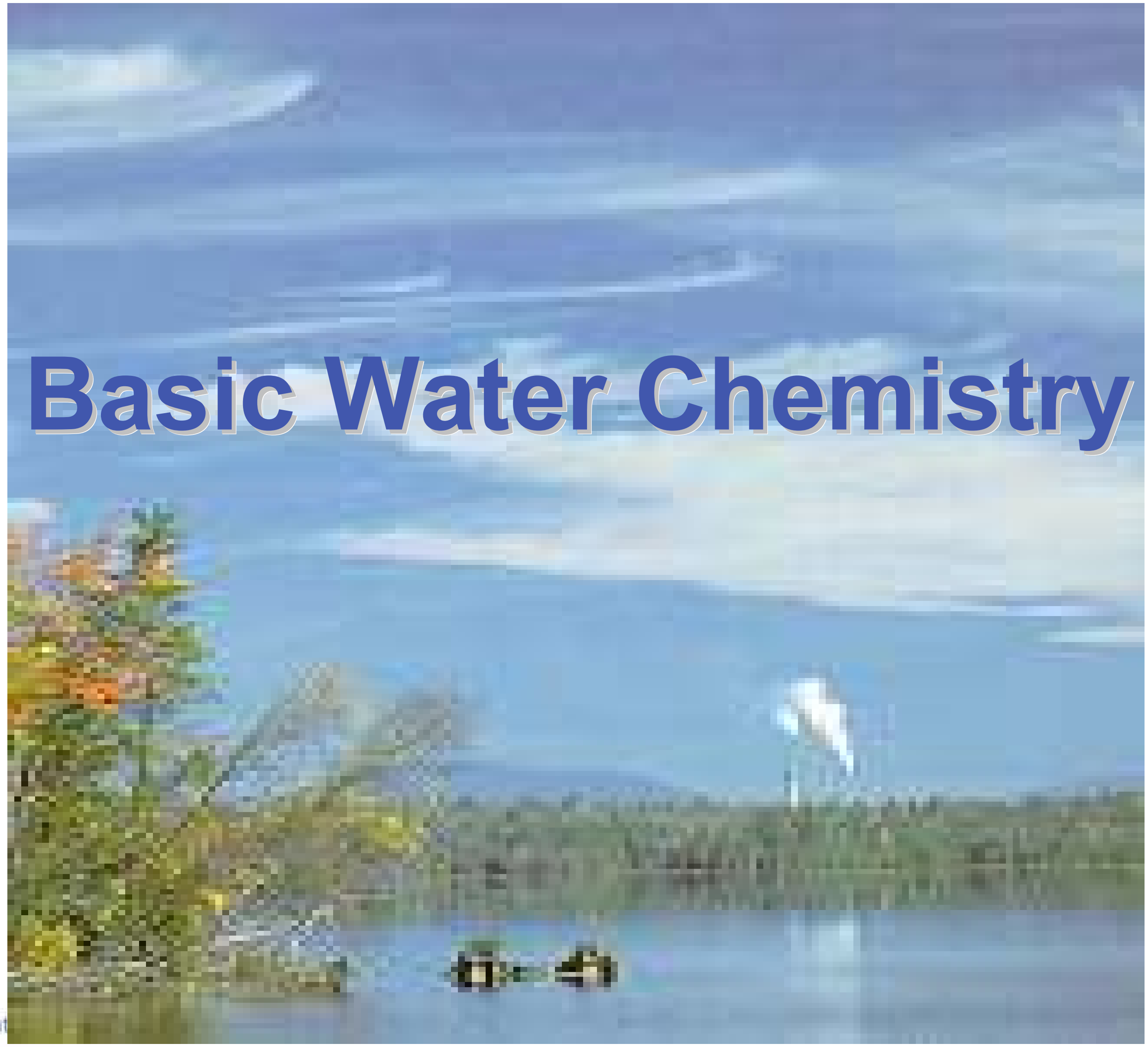
INDEX

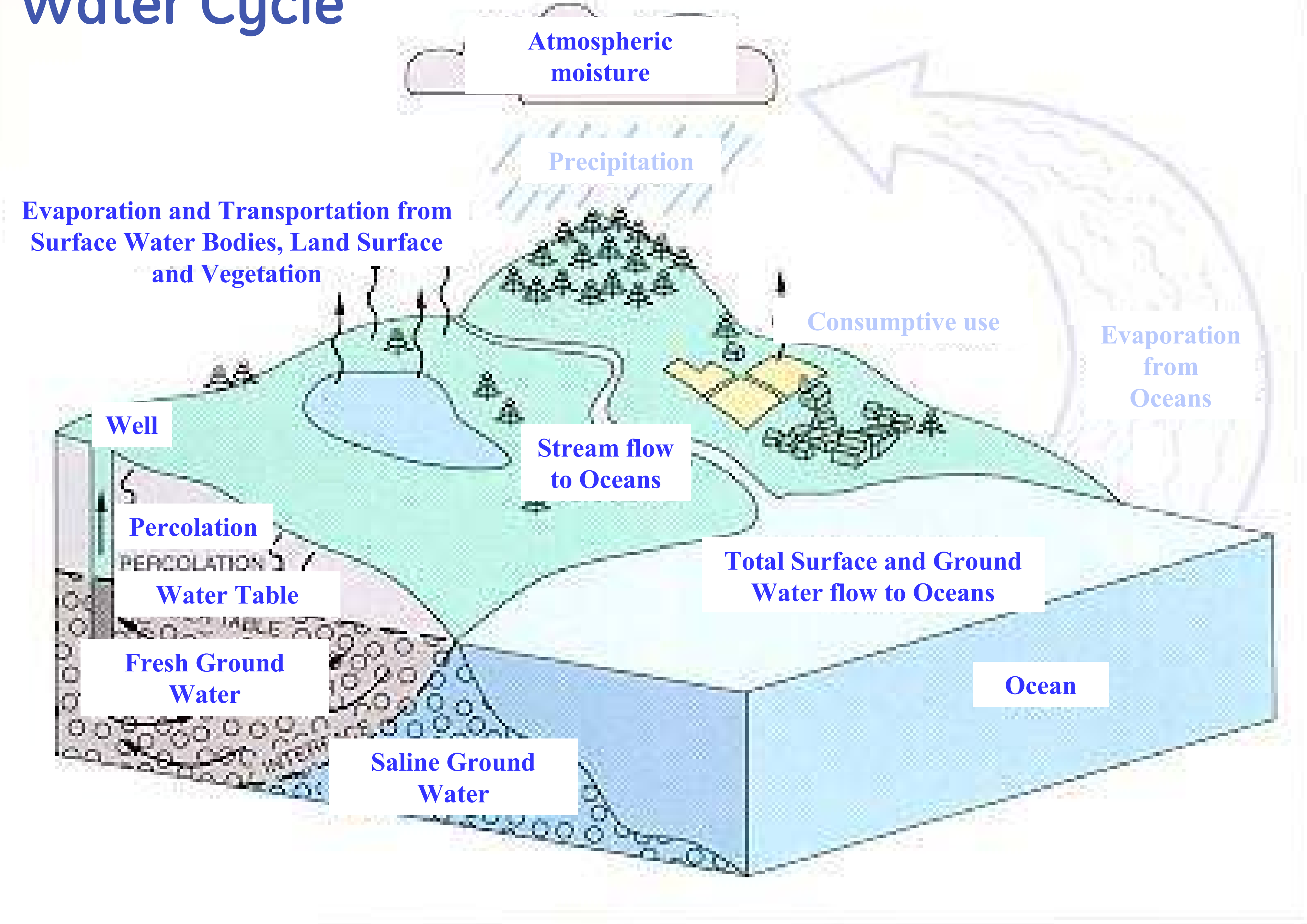
Chapter 1

BASIC WATER CHEMISTRY

Basic Water Chemistry



Water Cycle



Atmospheric moisture
Precipitation
Evaporation and Transportation from Surface Water Bodies, Land Surface and Vegetation
Consumptive use
Evaporation from Oceans
Well
Stream flow to Oceans
Percolation
PERCOLATION
Water Table
Total Surface and Ground Water flow to Oceans
Fresh Ground Water
Ocean
Saline Ground Water

WATER

Water is the UNIVERSAL SOLVENT and dissolves to some degree every known substance

Water will contain impurities in the form of dissolved solids, suspended solids and dissolved gasses

It is essential for industry that abundant supplies are continuously available

SOURCES of WATER

- Surface Water
  - > Lower quantities of Solubilised Minerals
  - > High amounts of Particulate Matter
  - > Variable Organic Matter Content
  - > Influences from Terrain and Geological Composition
- Ground Water
  - > Higher Mineral content
  - > Less Suspended Solids
  - > Influences from Geological Composition
- Other Water Sources
  - > Recycled / Reclaimed Water
  - > Sea Water

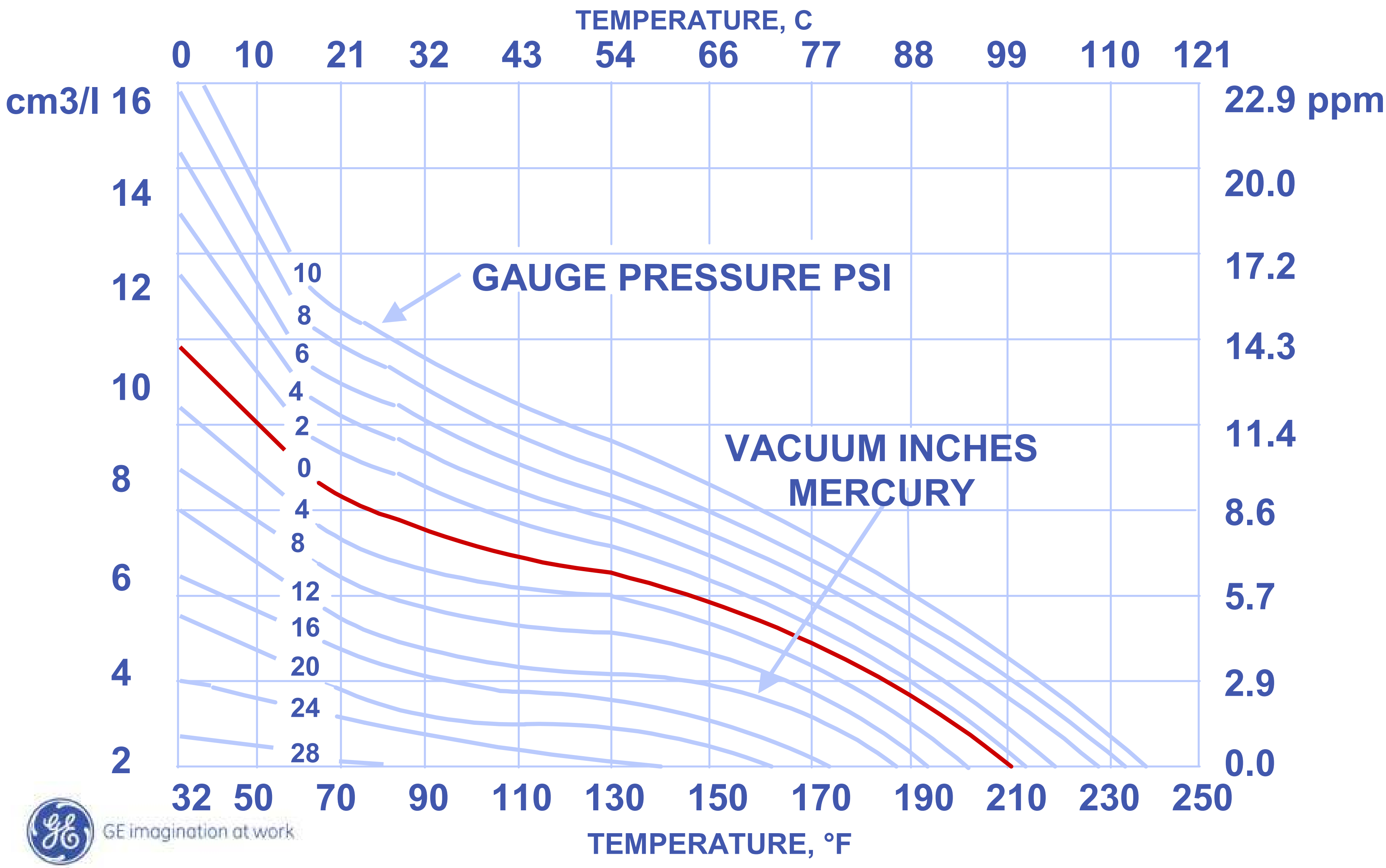
Purification of Water

- Suspended Solids
  - > Clarification
  - > Filtration
- Dissolved Salts
  - > Precipitating Softening
  - > Ion Exchange
  - > Reversed Osmosis
  - > Multiple Flash Evaporators
- Dissolved Gases
  - > Degasification
  - > Deaeration

ATMOSPHERIC GASES

- The atmosphere is a mixture of gases ,the main components are Nitrogen 78 %, Oxygen 21 %, Argon 0.9 % and Carbon Dioxide 0.033 %
  - Other gases include Hydrogen, Helium and Neon
- Nitrogen is Inert
- Oxygen :
  - The solubility is approx.10 mg/l at ambient temperature and pressure. The solubility decreases as temperature increases.

O2 SOLUBILITY IN WATER



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ATMOSPHERIC GASES

• **Carbon Dioxide** :

The solubility goes up to 1,700 mg/l in water.

$$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^{=}$$

> When Carbon Dioxide dissolves in water a WEAKLY ACIDIC solution is produced. This is commonly known as Carbonic Acid

> Typical pH is 6.5 to 6.8

INDUSTRIAL GASES

- Industrial gases produced by burning fossil fuels and by-products from industrial processes include Sulphur Dioxide / Trioxide, Nitrous Oxides, Hydrogen Sulphide and Ammonia

$$SO_2 + H_2O \longrightarrow H_2SO_3 \quad \text{Sulphurous Acid}$$
$$SO_3 + H_2O \longrightarrow H_2SO_4 \quad \text{Sulphuric Acid}$$

INDUSTRIAL GASES

- Nitrous Oxides

  > These include Nitrous Oxide NO

  Nitrogen Dioxide NO_2

  Dinitrogen Tetraoxide N_2O_4

- Hydrogen Sulphide

  H_2S in $H_2O \longrightarrow H^+ + HS^-$ Bisulphide

- Ammonia

  $NH_3 + H_2O \longrightarrow OH^- + NH_4^+$ Ammonium

DISSOLVED SALTS

- Water dissolves, to some extent, all known substances. However from a water treatment point of view we are mainly concerned with the salts of Calcium, Magnesium and to a lesser extent Sodium and Potassium.
- **The salts of Calcium and Magnesium are known as HARDNESS salts .**
- In most naturally occurring waters the Calcium concentration is higher than the Magnesium concentration.

In sea waters the reverse is true .

DISSOLVED SALTS

- Typical Calcium and Magnesium salts are :

Bicarbonates	$Ca(HCO_3)_2$	$Mg(HCO_3)_2$
Carbonates	$CaCO_3$	$MgCO_3$
Chlorides	$CaCl_2$	$MgCl_2$
Sulphates	$CaSO_4$	$MgSO_4$
Silicates	$CaSiO_3$	$MgSiO_3$

UNITS OF CONCENTRATION

- Dosage rates for continuous feed are expressed as mg/l on either BLOWDOWN or MAKE UP water flow for cooling systems.
- Shot doses are expressed as mg/l based on SYSTEM VOLUME:
  - 1 ppm equals:
    - 1 mg / l of water
    - 1000 mg/m^3 of water
    - 1 g/m^3 of water
    - 1 kg /1000 m^3 of water
- In some instances solution strength is expressed as a percentage:
  - 1 % solution = 10,000 mg/l or 10,000 ppm

UNITS OF CONCENTRATION

Parts per Million	ppm = mg/l
Parts per Billion	ppb = μg/l

Normally hardness and alkalinity are expressed as mg/l CaCO3.

This allows us to calculate the concentration of the different ionic species present in any given sample

Total hardness	150 ppm as $CaCO_3$
Calcium hardness	100 ppm as $CaCO_3$
Magnesium hardness	50 ppm as $CaCO_3$
M-Alkalinity	80 ppm as $CaCO_3$
Chloride	40 ppm as Cl^-

Corrosion Rate Measurement

- mils per year = 1/1000 inch per year
- mm/y = millimetres per year

> 1 mpy = 0.025 mm/y (0.0254)
> 1 mm/y = 40 mpy

Other important Parameters

pH

Alkalinity

Conductivity*

Chloride

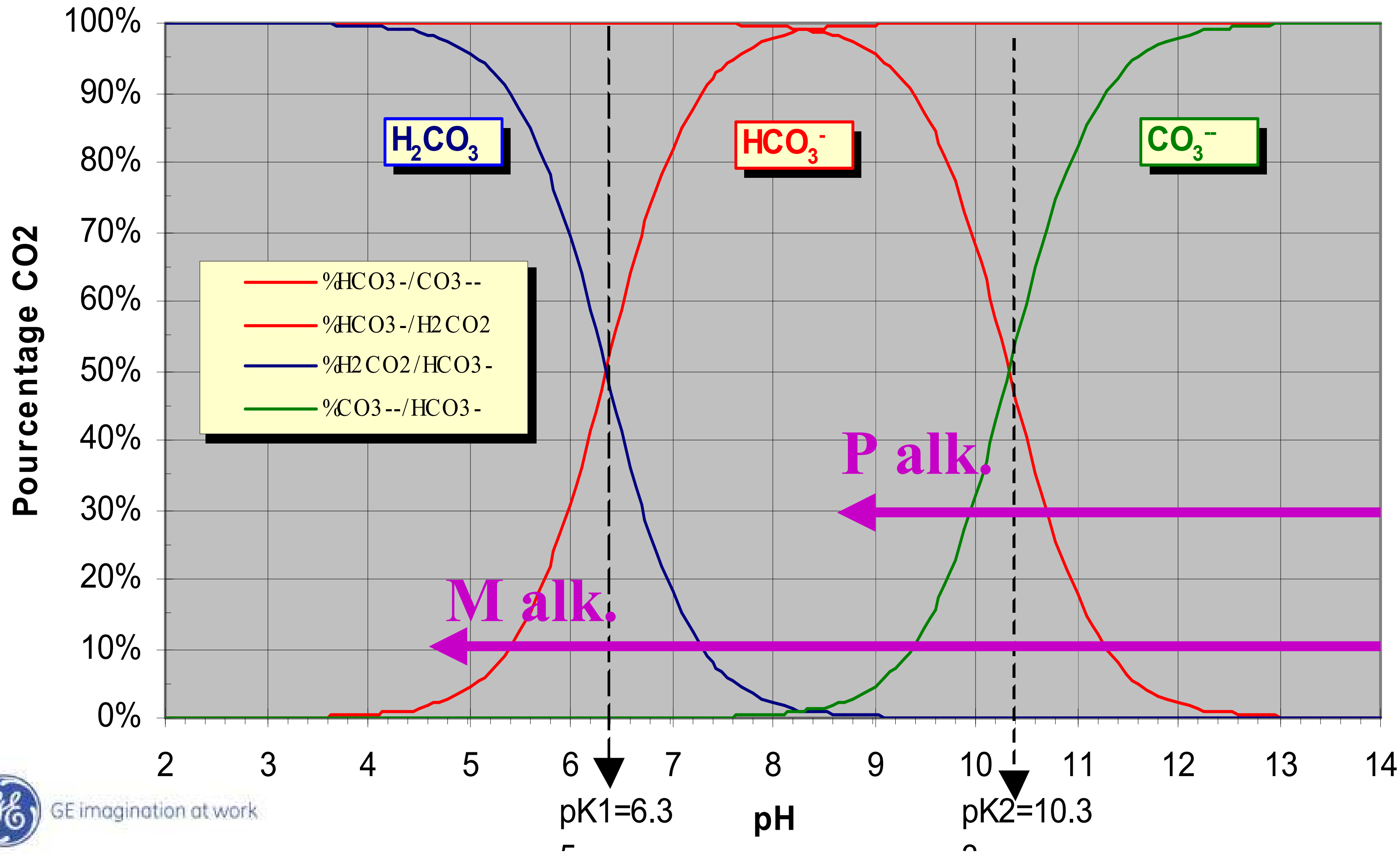
Sulphate

Soluble Iron (in Make Up Water)

Manganese

* essentially Total Dissolved Solids (TDS)

Carbon dioxide species versus pH in natural waters



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P Alkalinity

- P = Alkalinity - phenolphthalein alkalinity (pH=8.3)
  - > This titration includes all the HYDROXIDE and half of the CARBONATE

$$H^{+} + OH^{-} \longrightarrow H_2O$$

$$H^{+} + CO_3^{2-} \longrightarrow HCO_3^{-}$$

M Alkalinity

- M Alkalinity - methyl orange alkalinity (pH=4.4)
  - Also known as the TOTAL ALKALINITY
  - This titration includes all the HYDROXYDE and all the CARBONATE and all the BICARBONATE.

$$H^+ + OH^- \longrightarrow H_2O$$

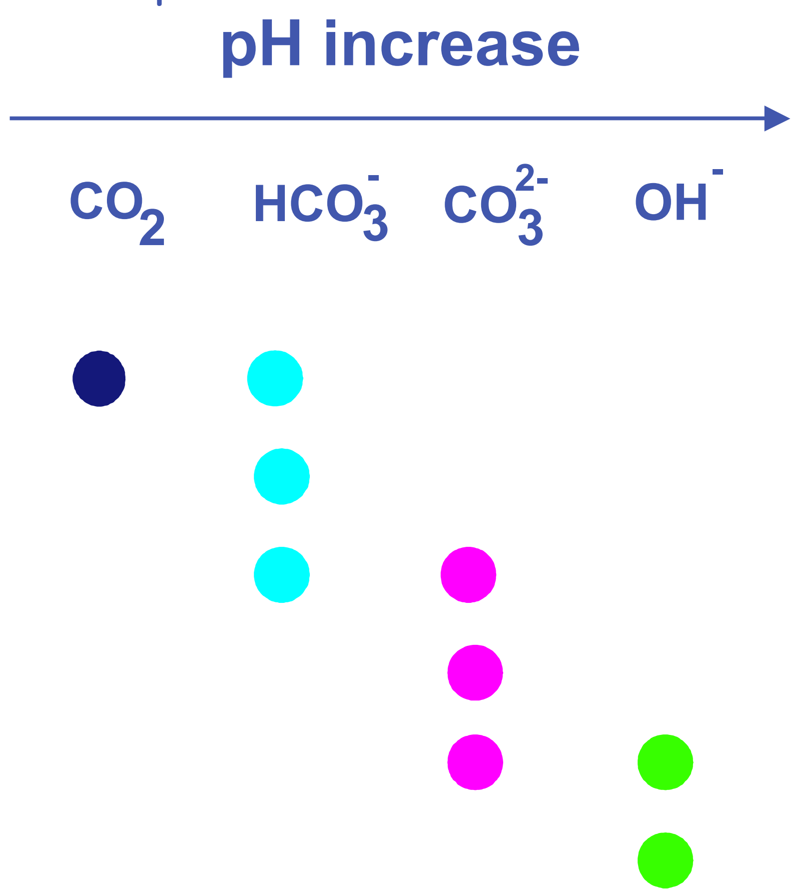
$$2H^+ + CO_3^{2-} \longrightarrow CO_2 + H_2O$$

$$H^+ + HCO_3^- \longrightarrow CO_2 + H_2O$$

  - Other indicators used are BDH 4.5 and bromocresol green/methyl red

P and M-Alkalinity

If we consider the series carbon dioxide, bicarbonate, carbonate and hydroxide we find that only adjacent pairs can co-exist



Chapter 2

COOLING SYSTEMS

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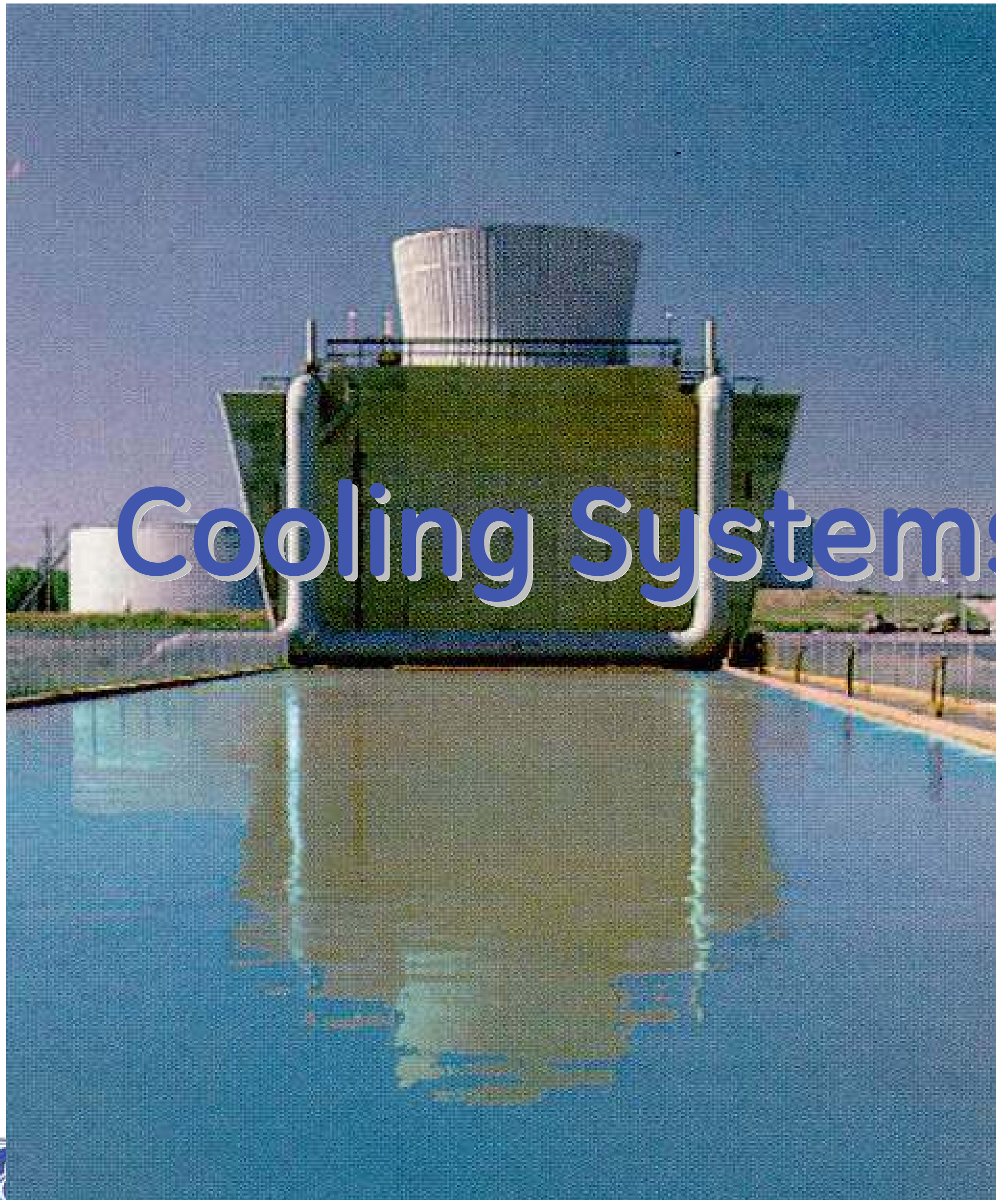
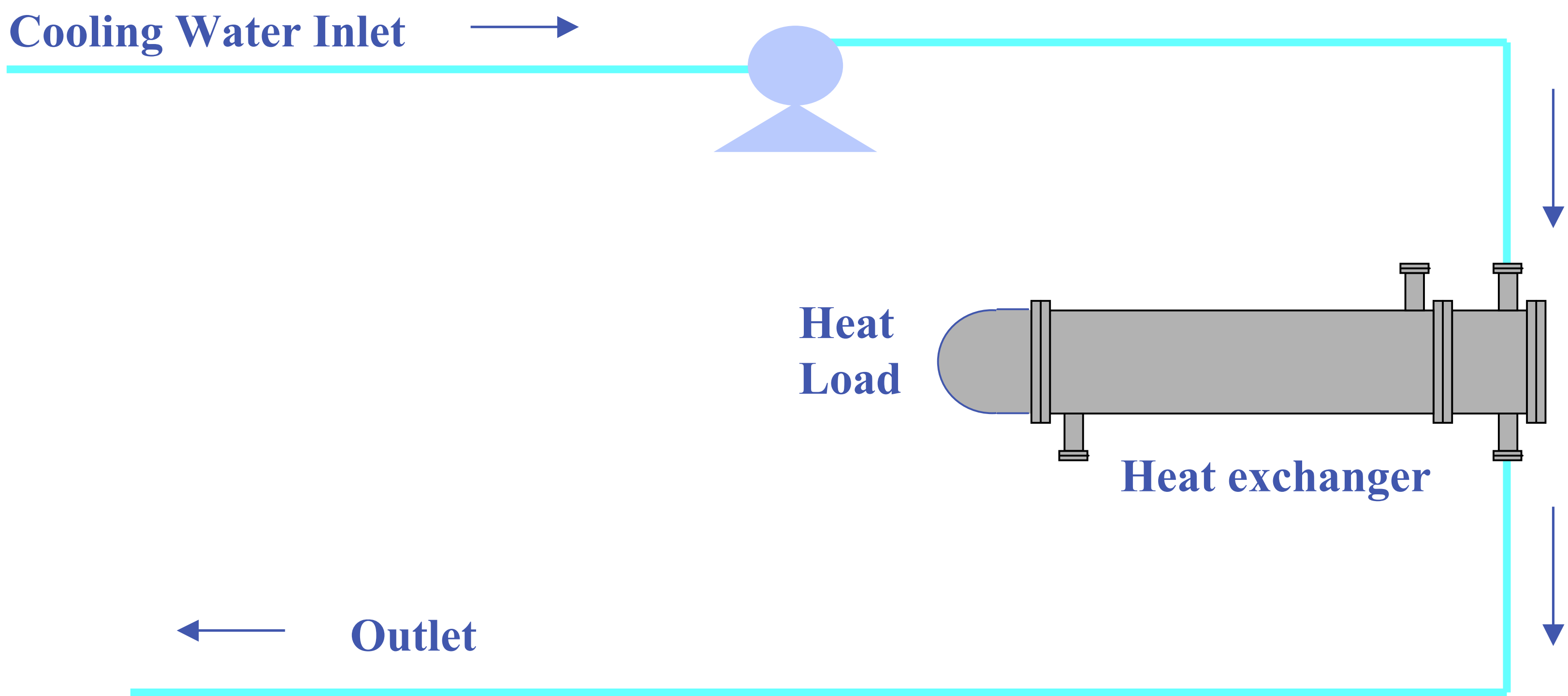
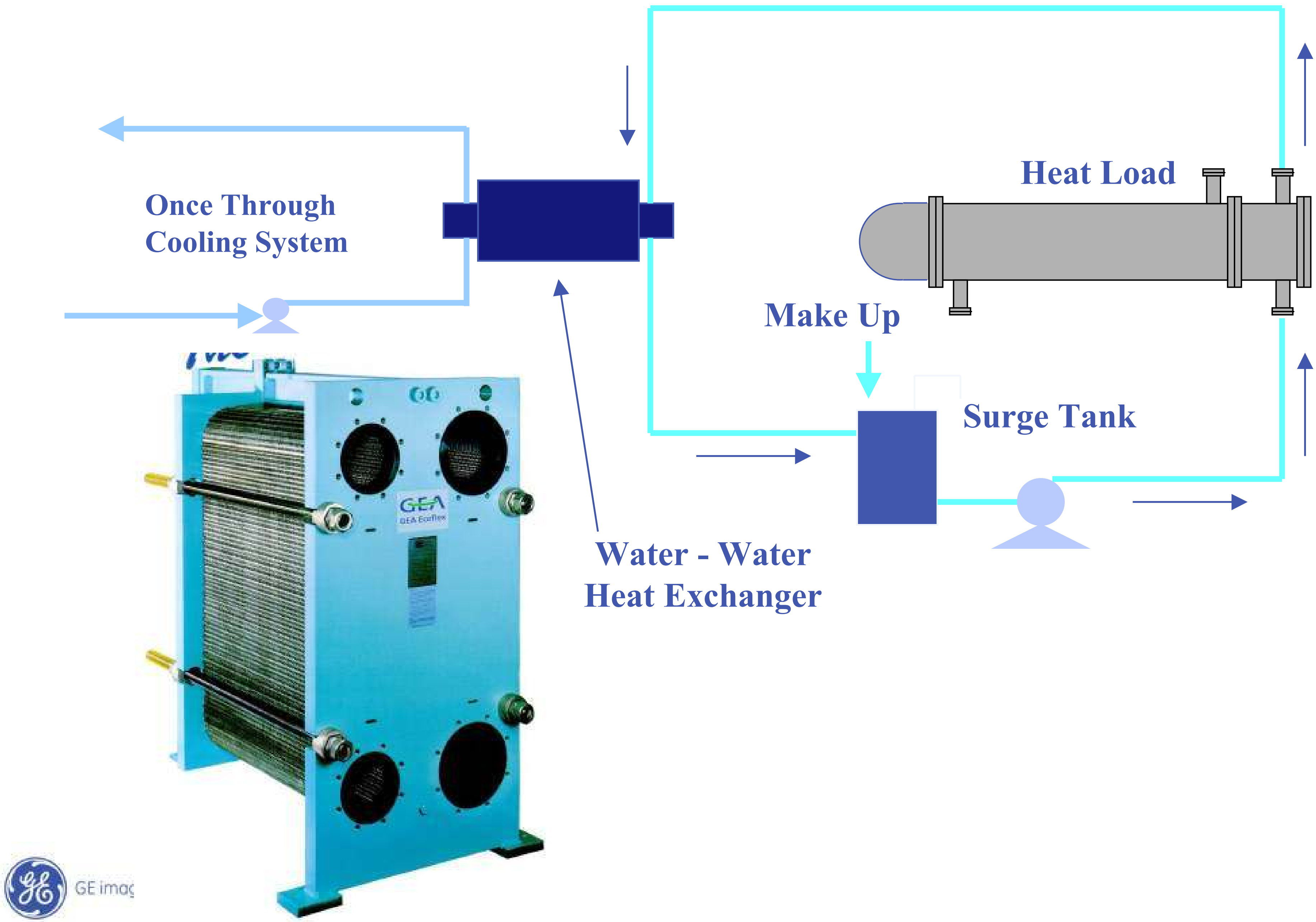
Cooling Systems



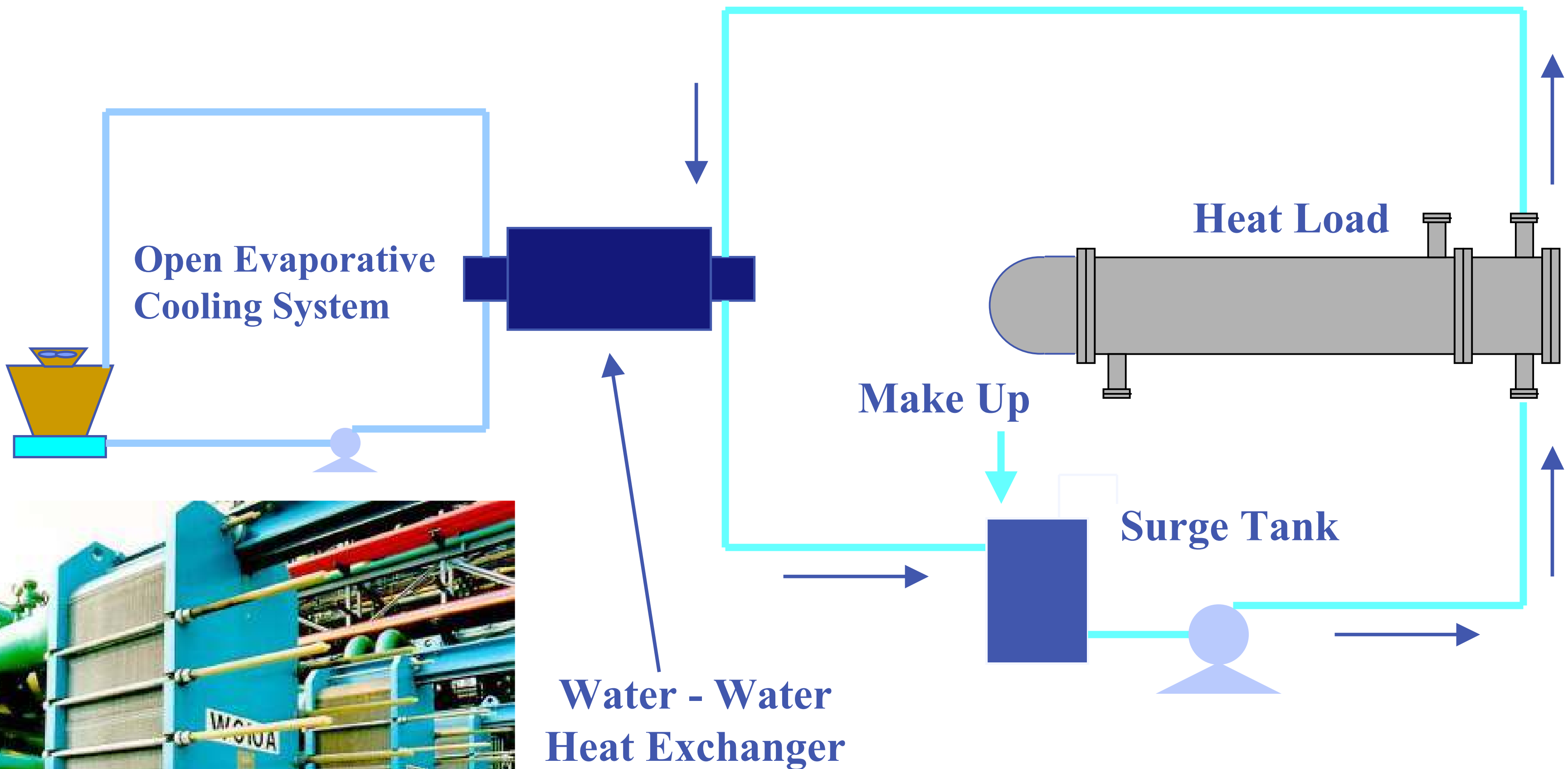
Once Through System



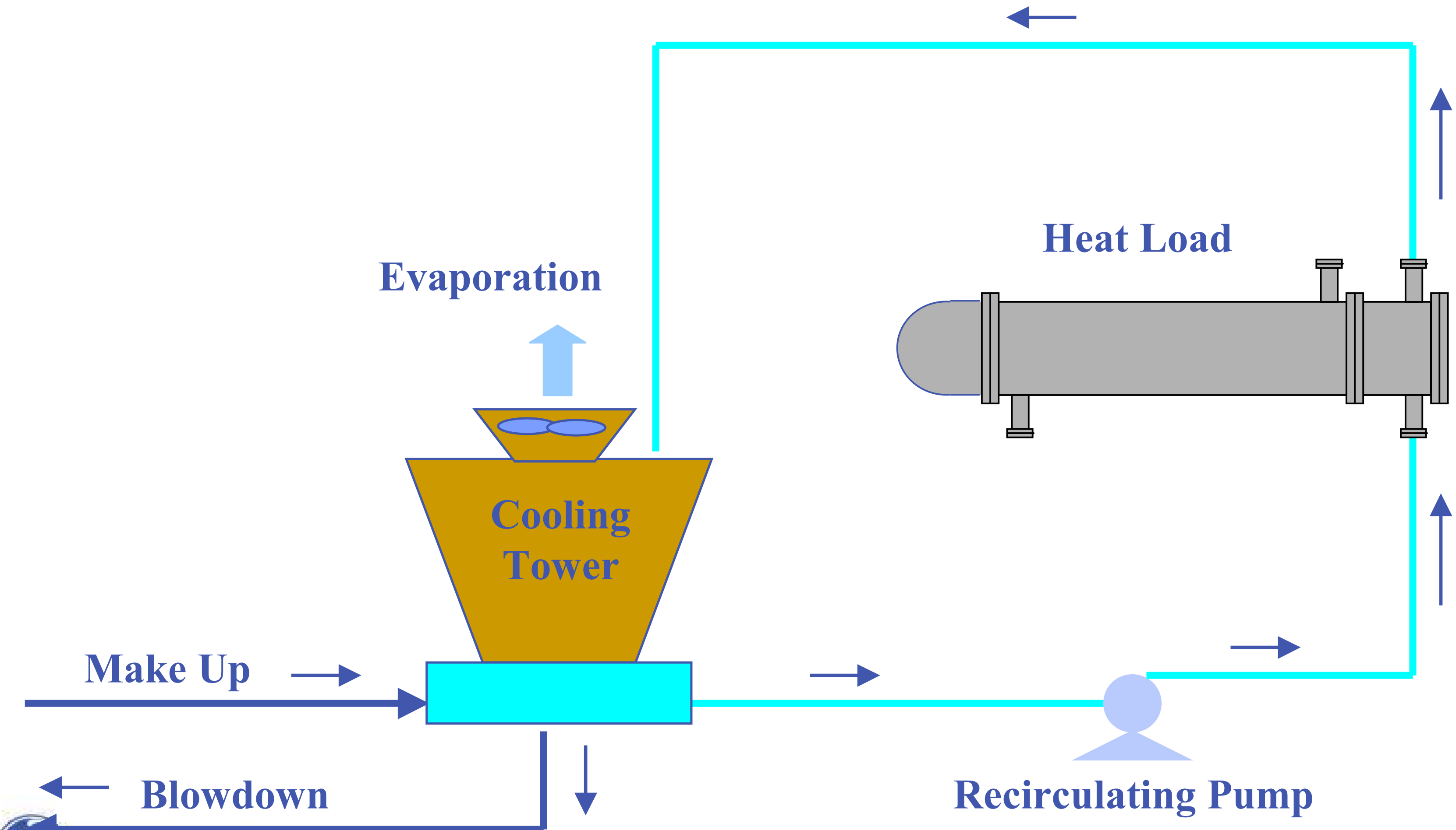
Closed Recirculating System



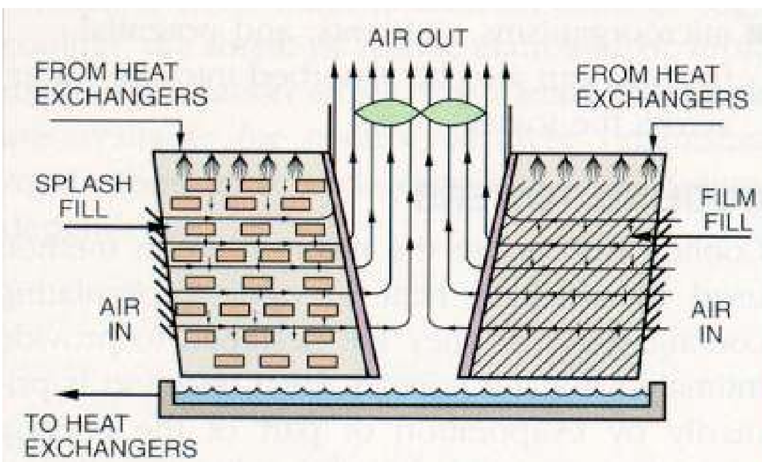
Closed Recirculating System



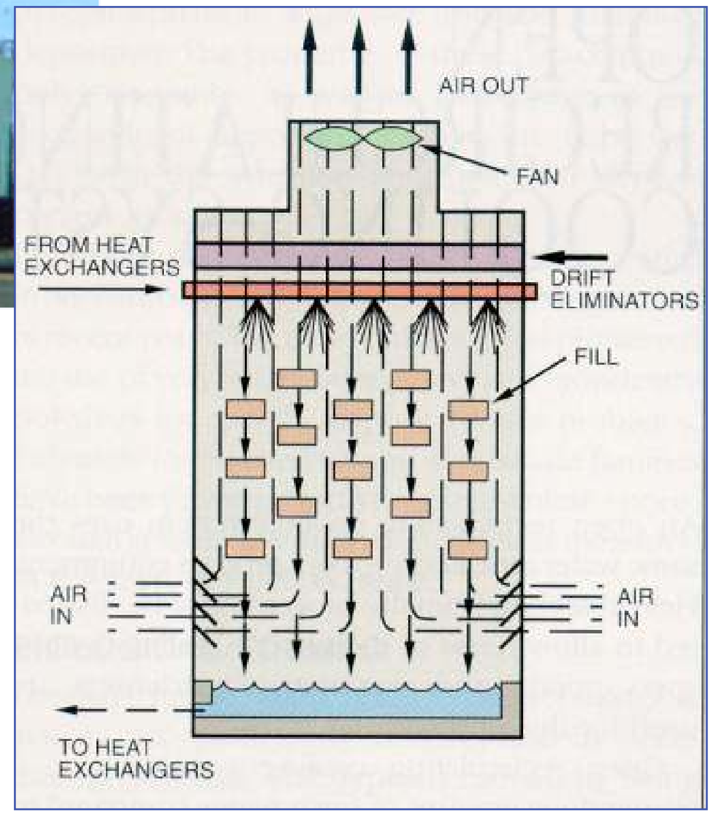
Open Evaporative System



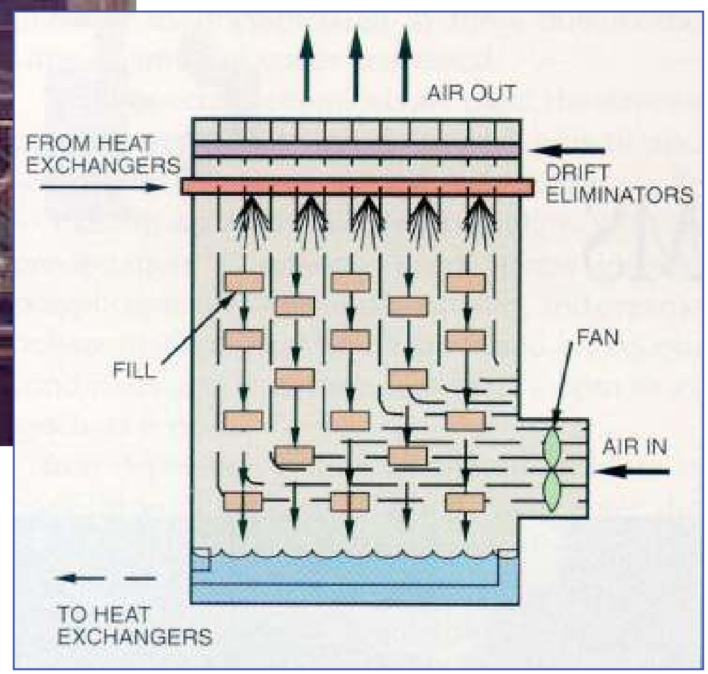
Induced Draft Cross Flow Cooling Tower



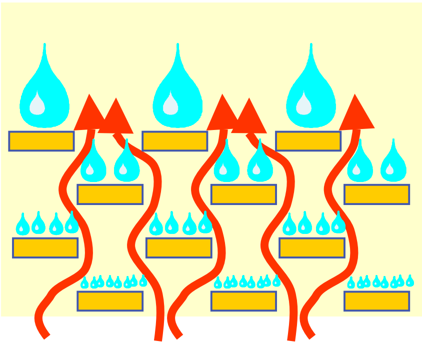
Induced Draft Counter Flow Cooling Tower



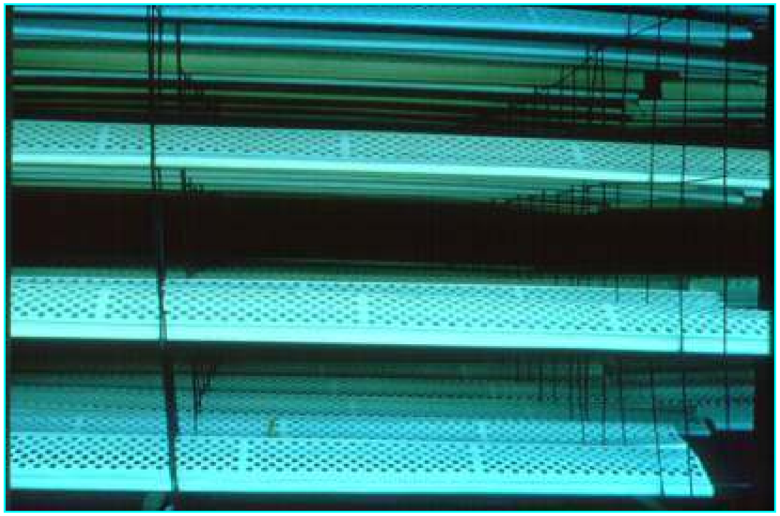
Forced Draft Cooling Tower



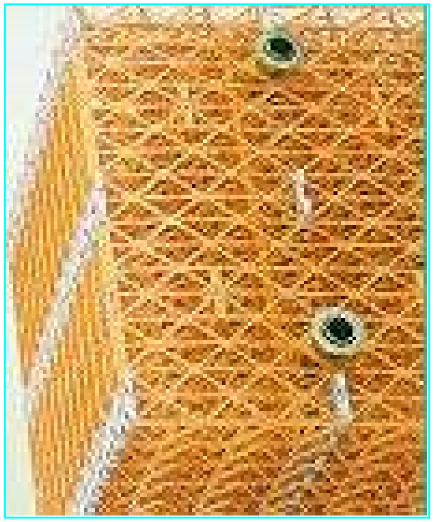
Splash Packing



Plastic



Splash Fill



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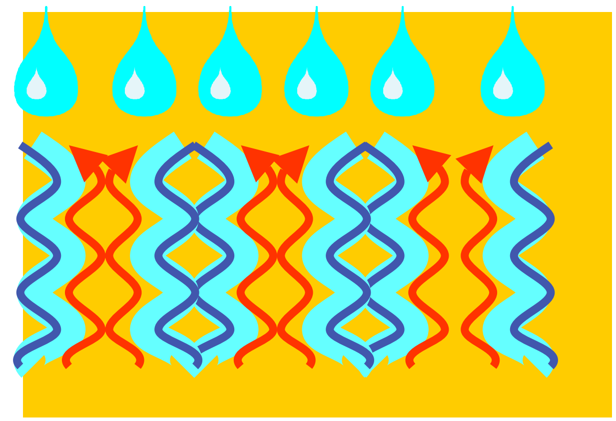
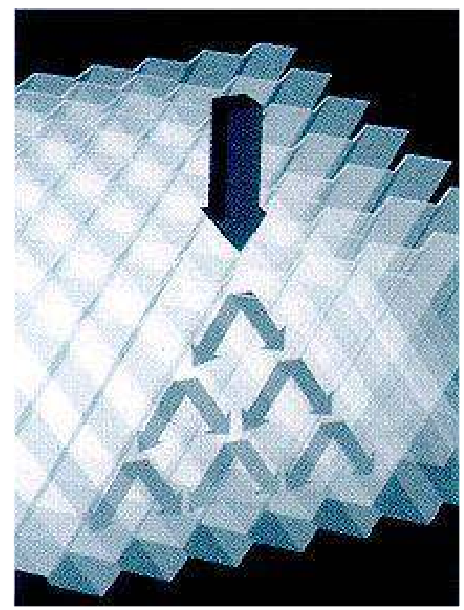
Plastic Film Packing

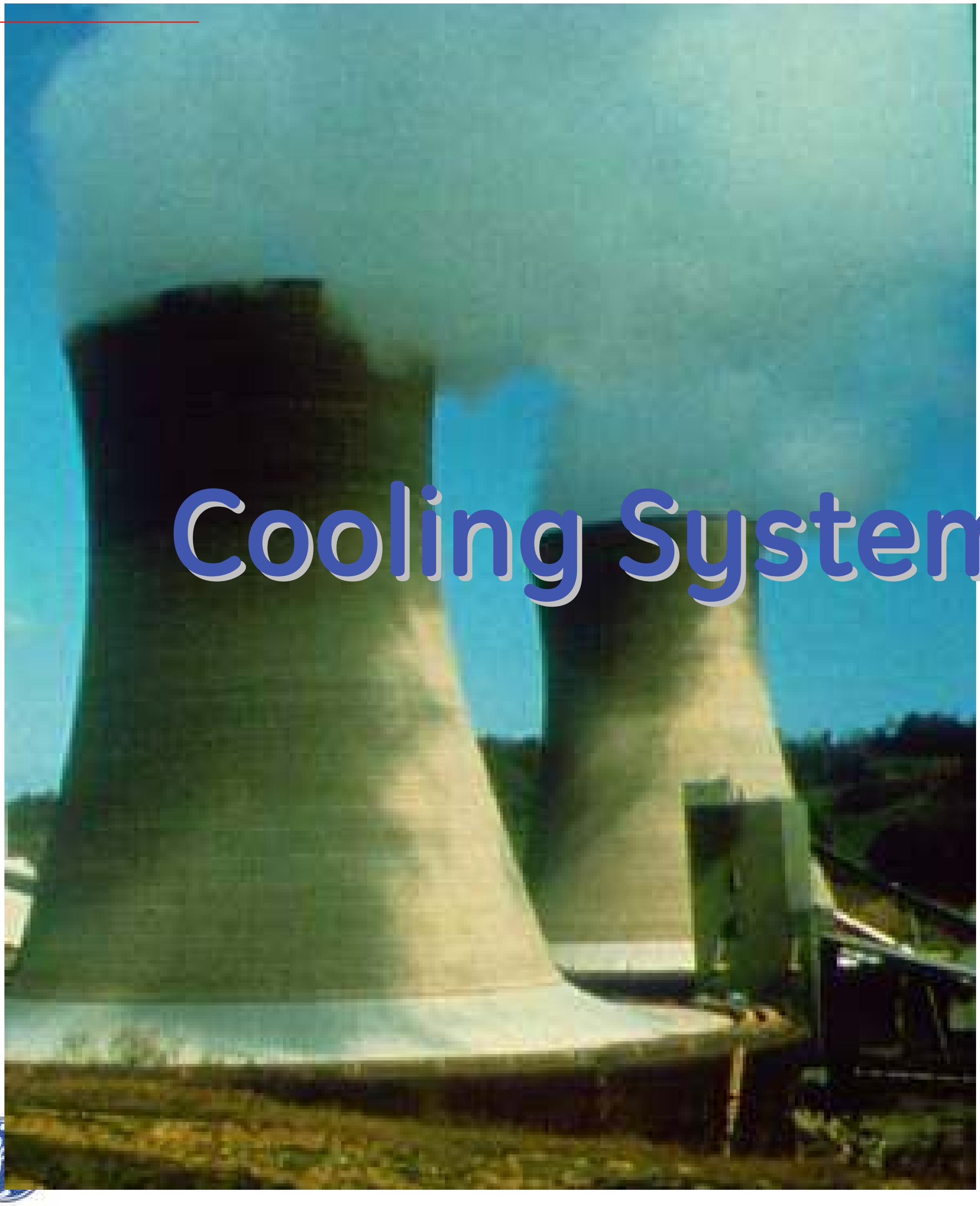




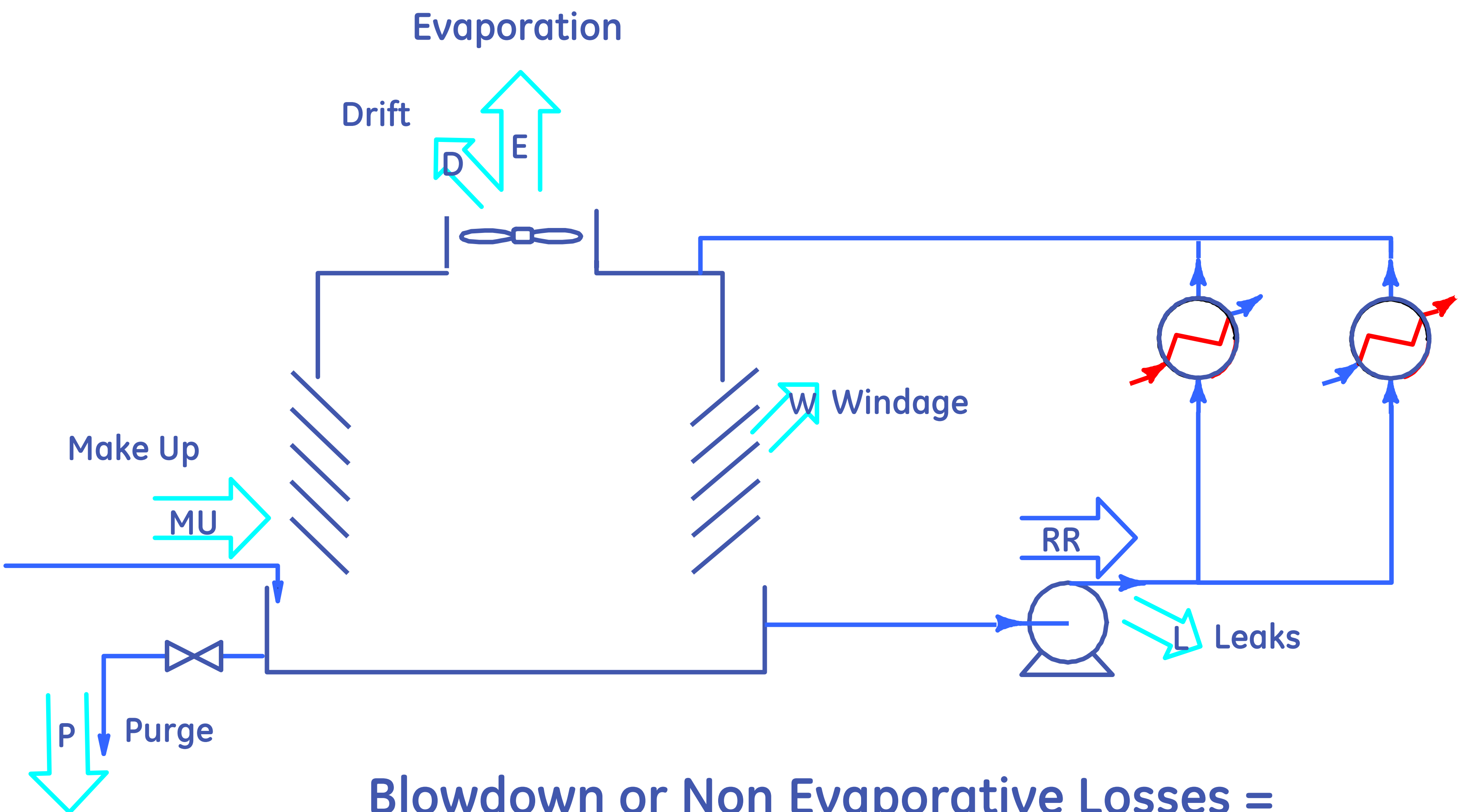
Chapter 3

COOLING SYSTEM HYDRAULICS

GE Betz



Cooling System Hydraulics



Blowdown or Non Evaporative Losses = Purge + Windage + Drift + Leaks

LATENT HEAT OF VAPORISATION

- Latent Heat of Water is 556 kcal/kg
- Evaporation of 1 kg water dissipates 556 kcal
- Evaporation of 1 kg water from 100 kg of the (recirculating) water or 1% of the (recirculating) water reduces temperature by 5.56 °C

EVAPORATION RATE (E)

$$E\ (t/h) = \frac{RR\ (m^3/h) \times \Delta T\ °C \times E_f}{580} \quad @\ 30\ °C$$

$\Delta T°C = T_R C° - T_S C°$

where :

R = Return Water

S = Supply Water

$$E = 0{,}8\ \frac{RR \times \Delta T}{580}$$

E_f
1.0 %
0.9 %
0.8 %
0.7 %
0.6 %

I.e. 1,4% of RR at 10°C ΔT or 1% RR at 6 to 7°C de ΔT

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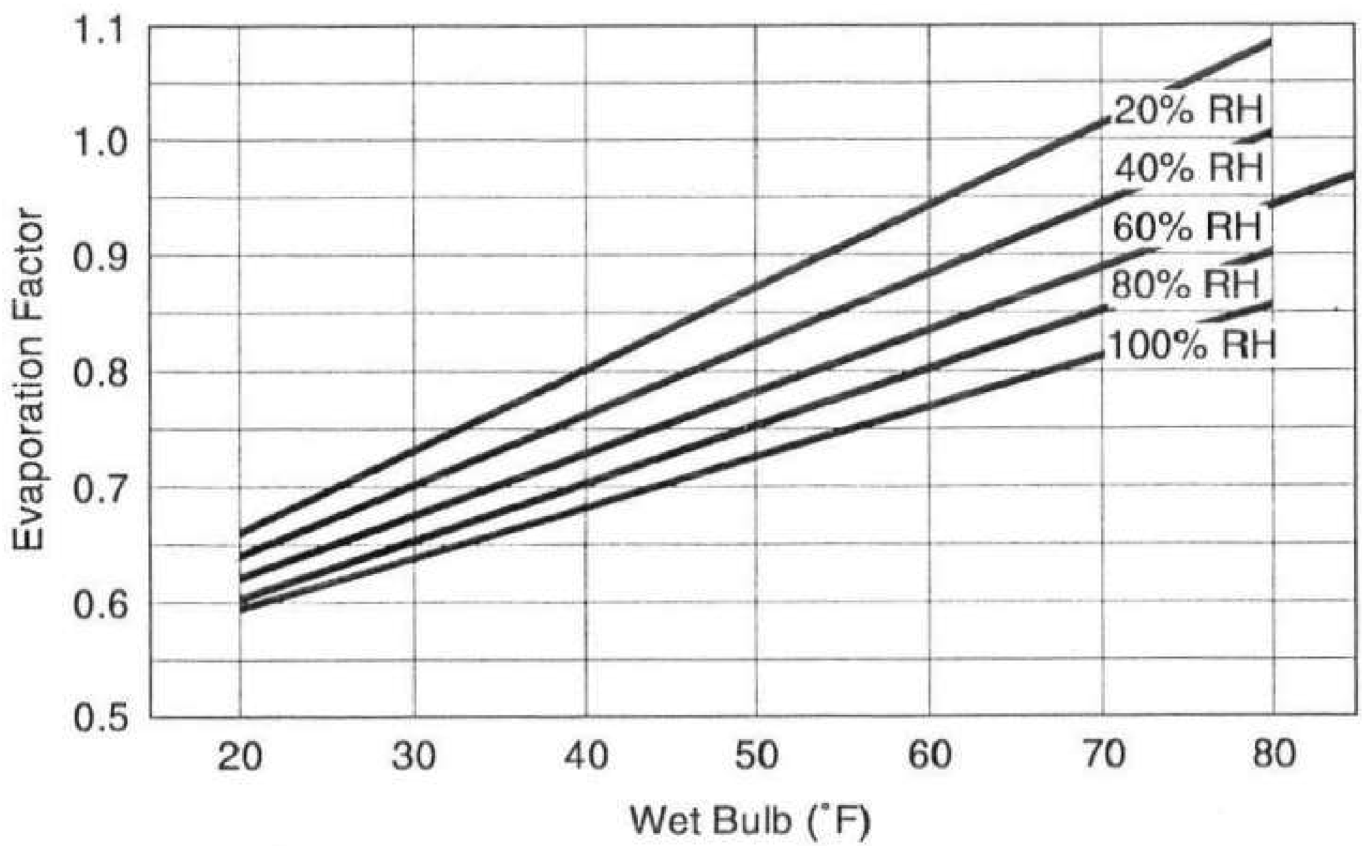
E_f Vs. wet-bulb temperature



Definitions

Cycles of Concentration (Cy)

$$Cy = \frac{\text{Concentration of "X" in Recirculating Water}}{\text{Concentration of "X" in Make Up Water}}$$

Blowdown Rate (BD)

$$BD(m^3/h) = \frac{E(m^3/h)}{(Cy - 1)}$$

Make Up Rate (MU)

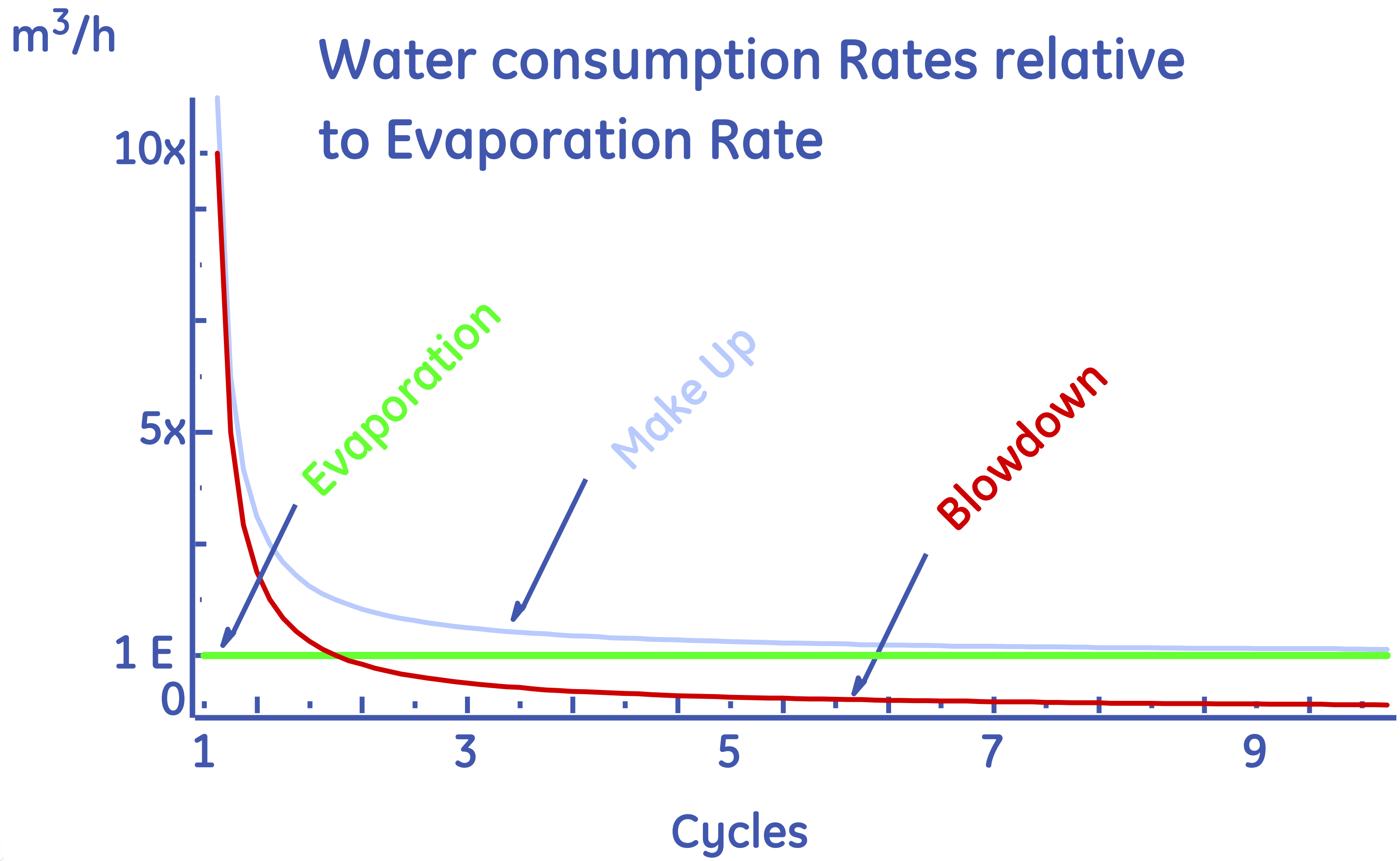
$$MU(m^3/h) = E(m^3/h) + BD(m^3/h)$$

$$MU\ (m^3/h) = BD(m^3/h) \times Cy$$

or

$$BD\ (m^3/h) = \frac{MU}{Cy}\ (m^3/h)$$

Make Up and Blowdown Rates



DEPLETION

$$C_t = C_\circ \, e^{\frac{-bt}{V}}$$

$$t = -\frac{V}{b}\left[\ln\left(\frac{C_t}{C_\circ}\right)\right]$$

$$b = -\frac{V}{t}\left[\ln\left(\frac{C_t}{C_\circ}\right)\right]$$

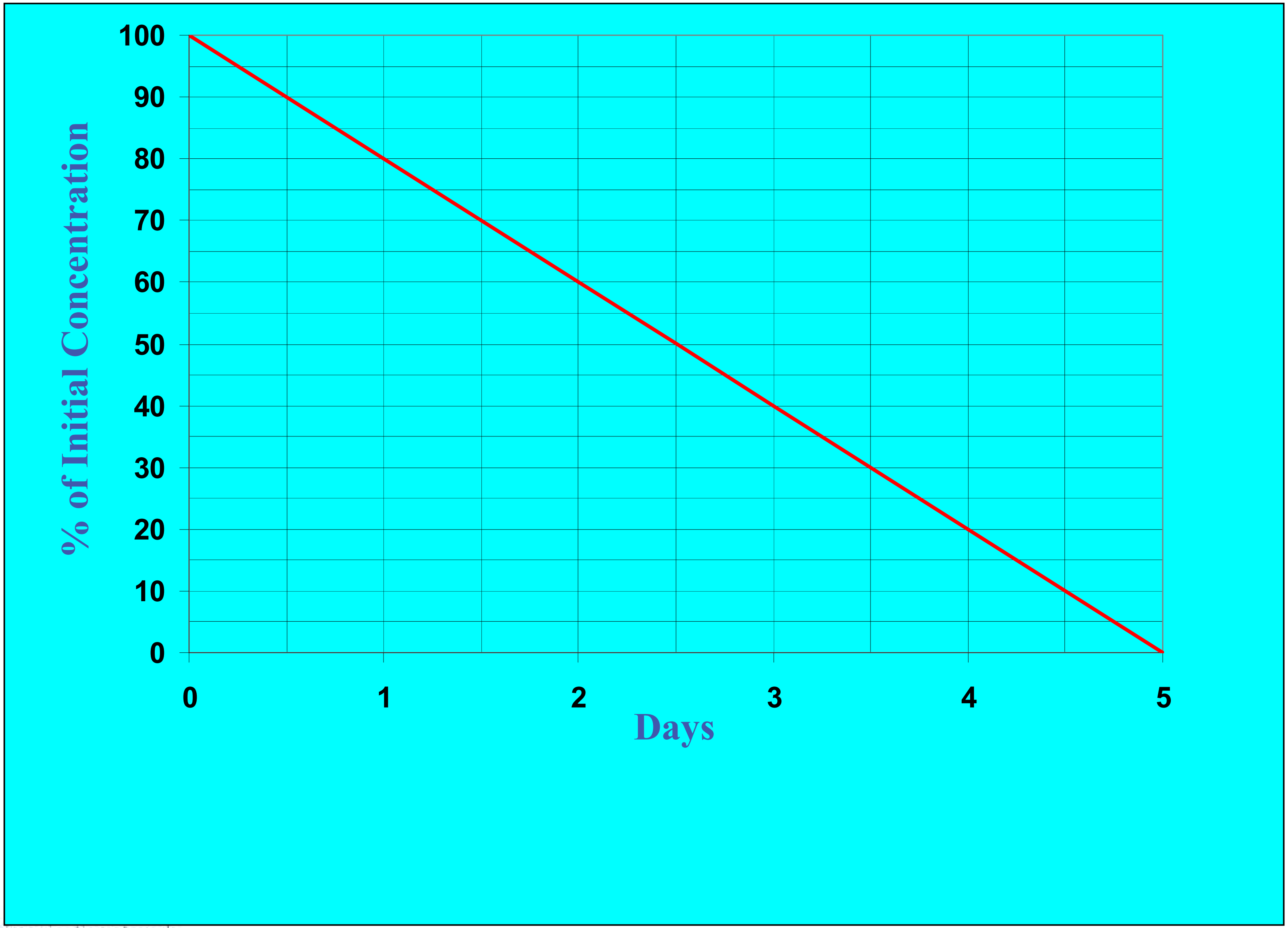
Depletion

V = 6000 cubic.m

BD = 1200 cubic.m per day

If 100 mg/l biocide is injected what is the remaining concentration after 3.5 days ?

DEPLETION



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SYSTEM HALF-LIFE

$$t = -\frac{V}{b} \ln \frac{C_t}{C_o} = -\frac{V}{b} k \log_{10}\frac{1}{2} = \frac{V}{b} k \log_{10} 2$$

$$t_{1/2} = \frac{V(m^3)}{b(m^3/h)} \times 0.6931$$

Note :
This can be approximated to

$$t_{1/2} = \frac{V}{b} \times 0.7$$

Chapter 4

OPEN EVAPORATIVE COOLING SYSTEM TREATMENT PROGRAMMES

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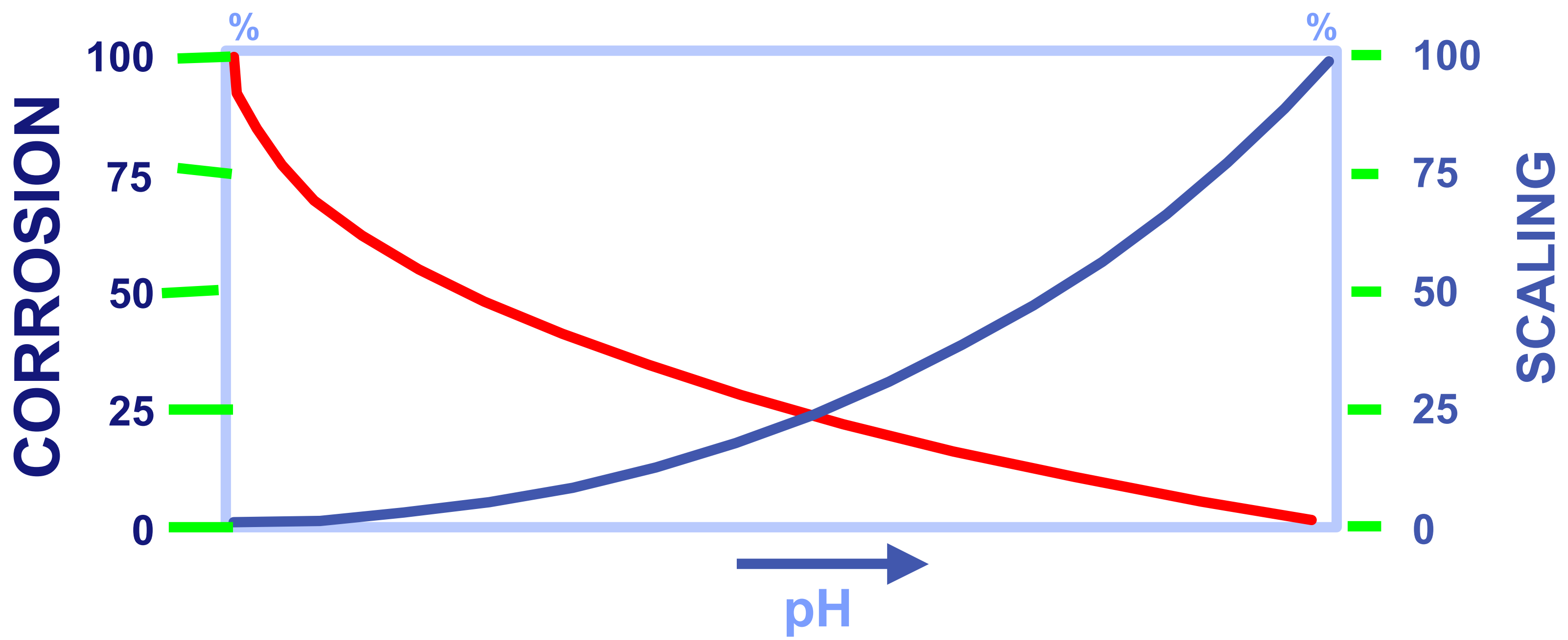
Treatment Objectives

The general objectives of the cooling water treatment program are:

- Control corrosion rate to prevent equipment failure.
- Prevent scale formation and deposition on heat transfer surfaces to maximise system performance
- Control microbiological activity and maintain system cleanliness.
- Allow the cooling system to operate at the optimum cycles of concentration

Scaling/corrosion as pH function



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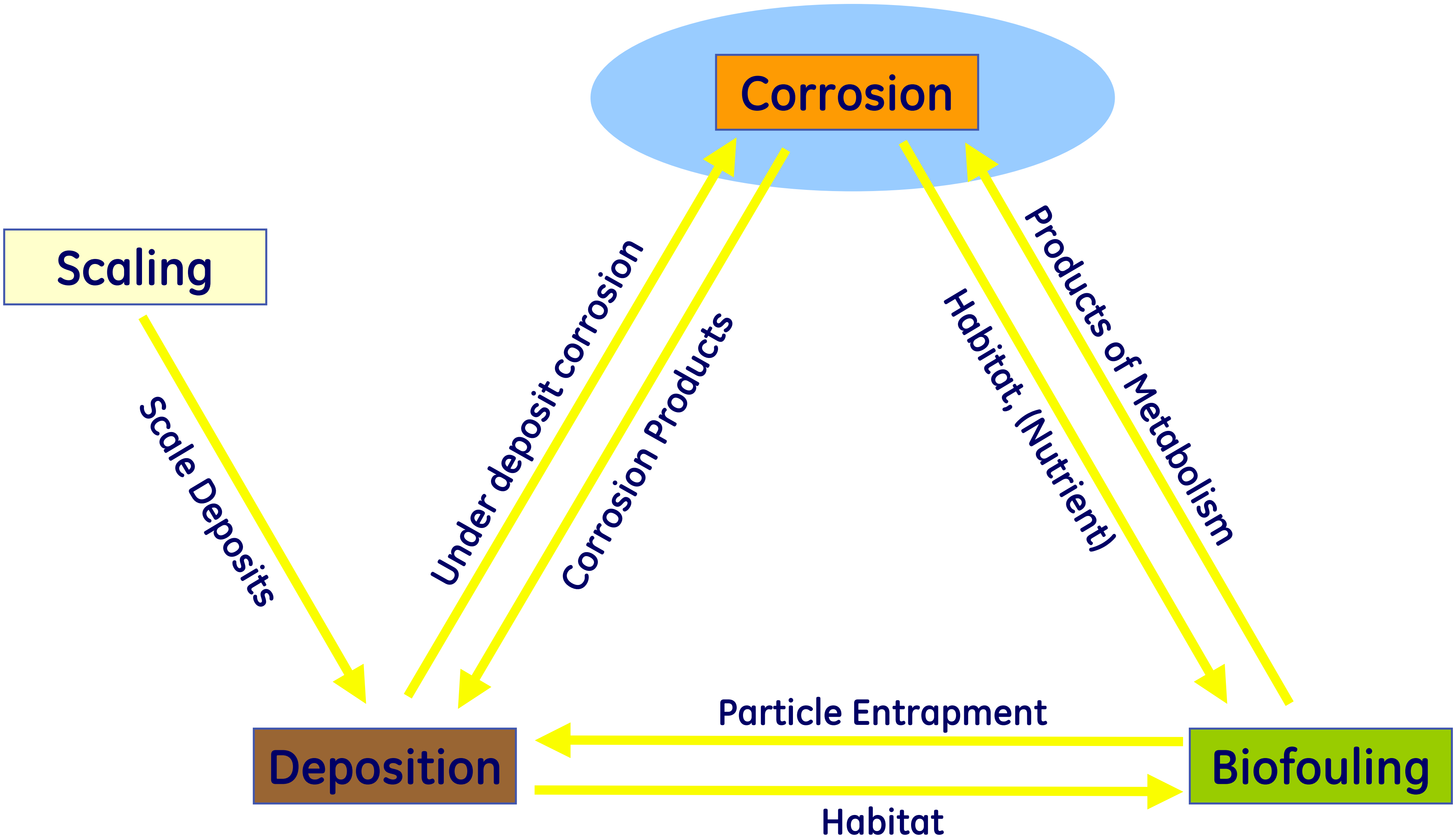
Water Treatment Concerns



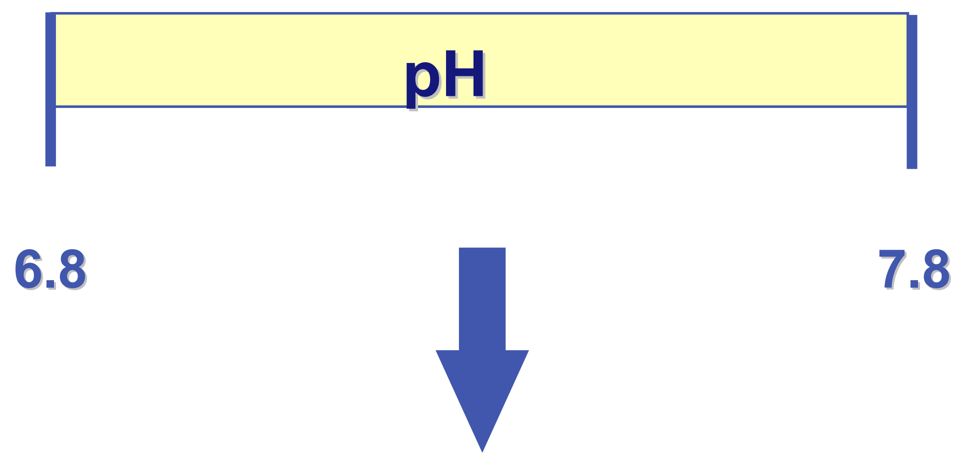
pH

6.8 — 7.8

AGGRESSIVE WATER

STRONG CORROSION INHIBITORS

GE Betz Technologies



DIANODIC

pH

7.8 9.0

SCALING WATER

STRONG SCALING INHIBITORS

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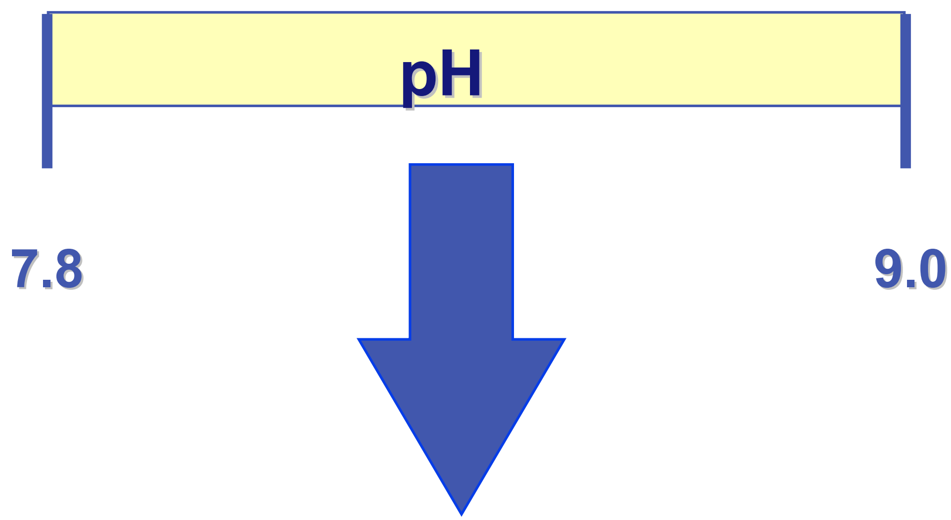


CONTINUUM

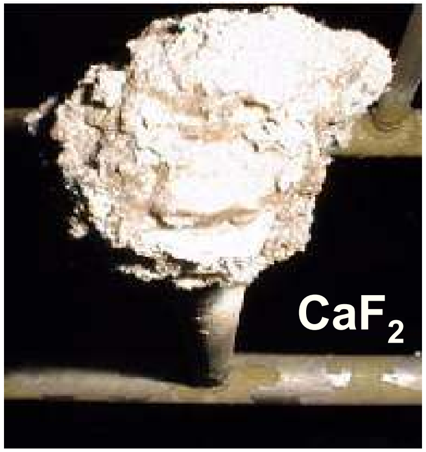
Chapter 4.1

SCALE INHIBITION TREATMENT PROGRAMMES

Scaling in Cooling Systems

$CaCO_3$
$CaSO_4$
$Ca_3(PO_4)_2$
$MgSiO_3$
$CaO.MgO.(SiO_2)_2$
SiO_2

Al_2O_3 , SiO_2
$Zn_3(PO_4)_2$
$Zn(OH)_2$
$FePO_4$
Calcium phosphonate



Scaling in Cooling Systems

Scale Formation

Scale Potential Depends On:

- Temperature
- pH
- Concentration Of Ions
- Velocity
- Agitation or Turbulence

Scaling in Cooling Systems

Scale Control

- Removing scale components from make-up water.

CaF_2

- Keeping scale salts in solution .

- Removing scale forming salts by precipitation.

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Scaling in Cooling Systems

Scale Control

Softening .

Demineralizing .

Reverse Osmosis.

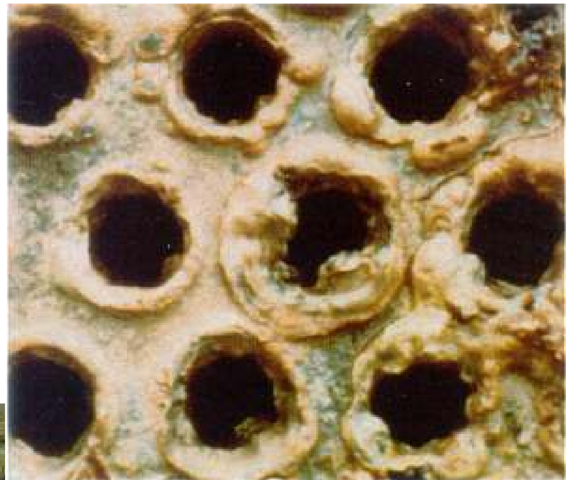
Acid Dosing .

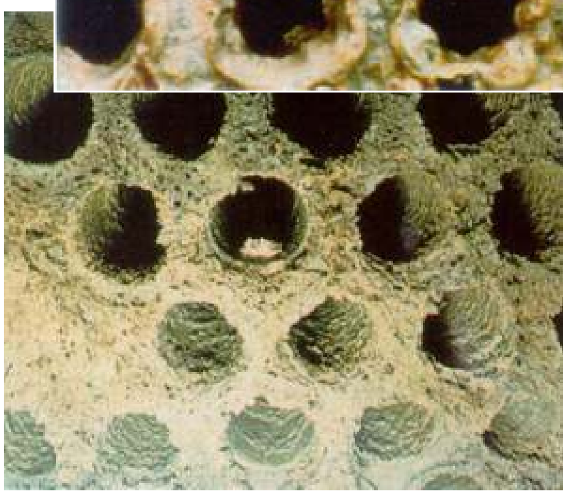
Scale Inhibitor .

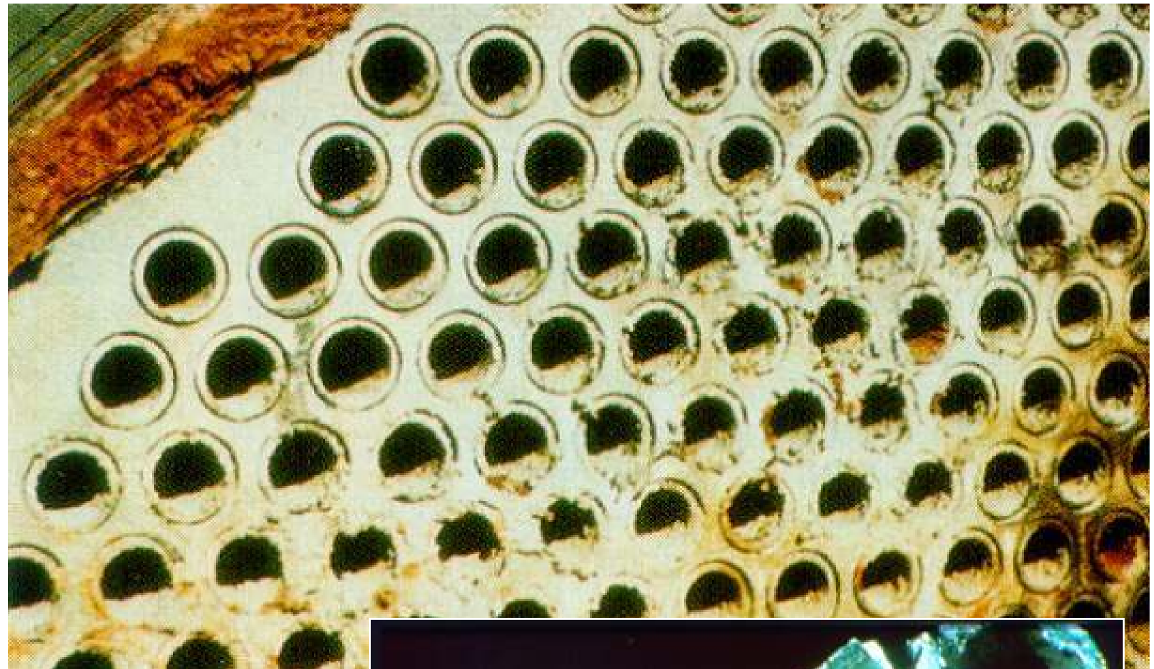
Polymer Dosing.

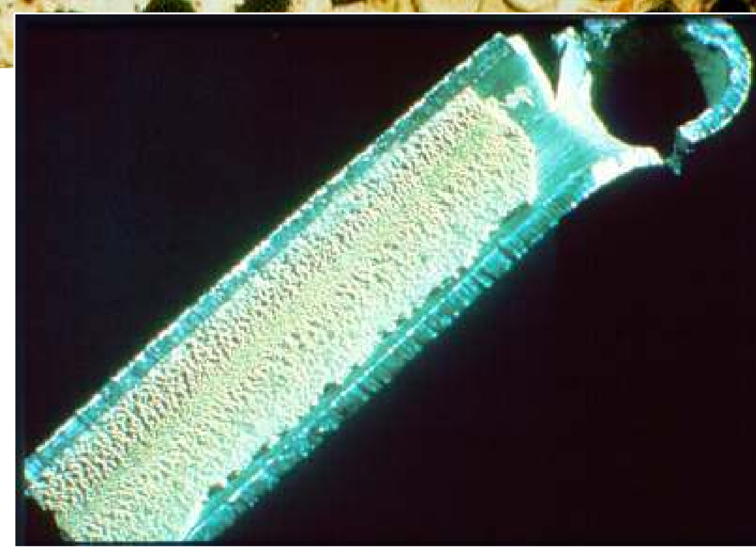
Decreasing Cycles of Concentration.

SCALE









Mineral Scale can form when SOLUBILITY IS EXCEEDED

FACTORS AFFECTING CALCIUM CARBONATE SCALE FORMATION

- Calcium (bicarbonate) concentration
- M alkalinity (bicarbonate concentration)
- Temperature (hottest skin temperature)
- pH (of the bulk water)

LANGELIER SATURATION INDEX

1936 Professor Langelier

"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

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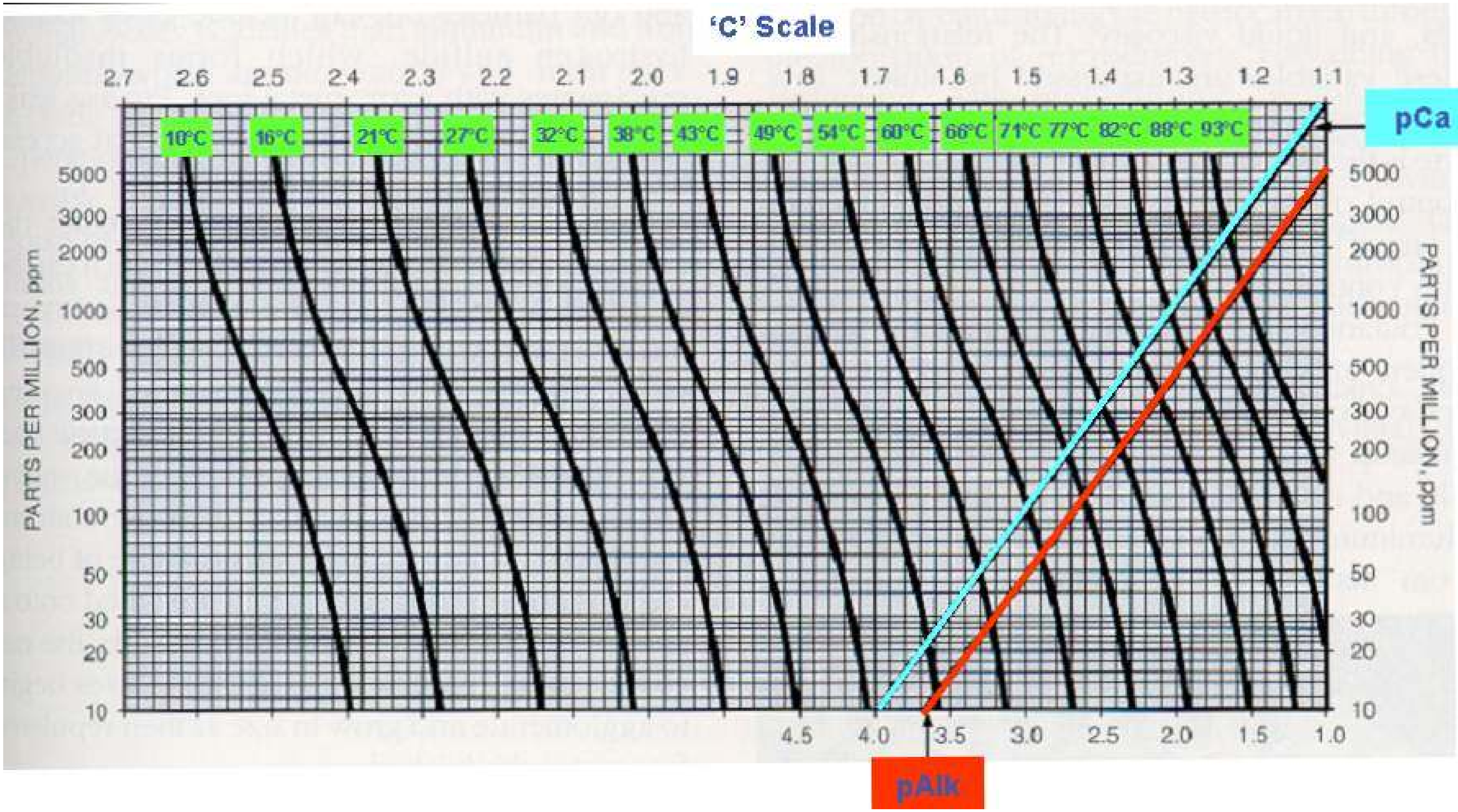
LANGELIER SATURATION INDEX



$pH_s = pCa + pAlk + C$

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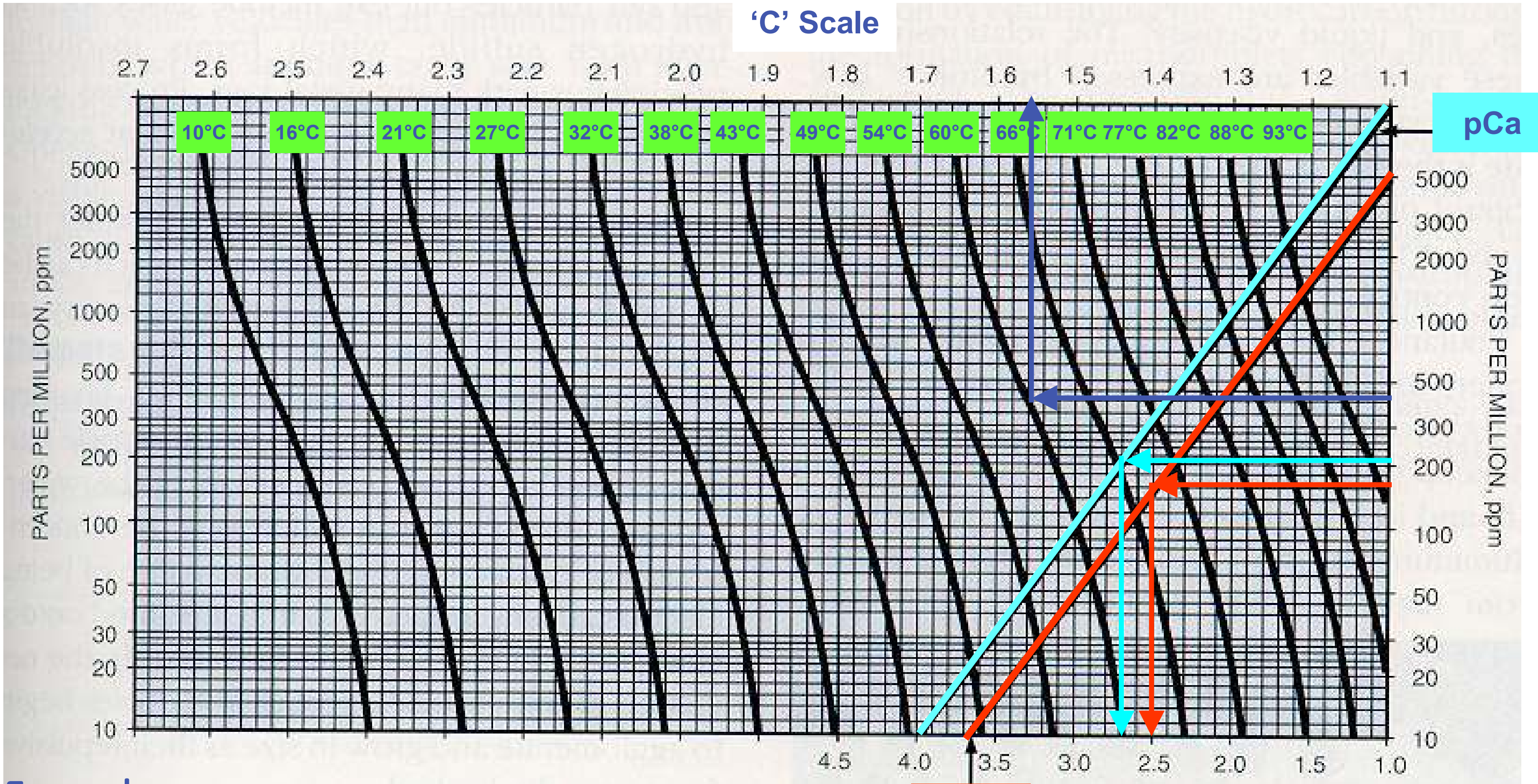

Example

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
pH of Cooling Water (pH_a)	7.80	Total (pH_s)	6.76

$LSI = pH_a - pH_s = +1.04$

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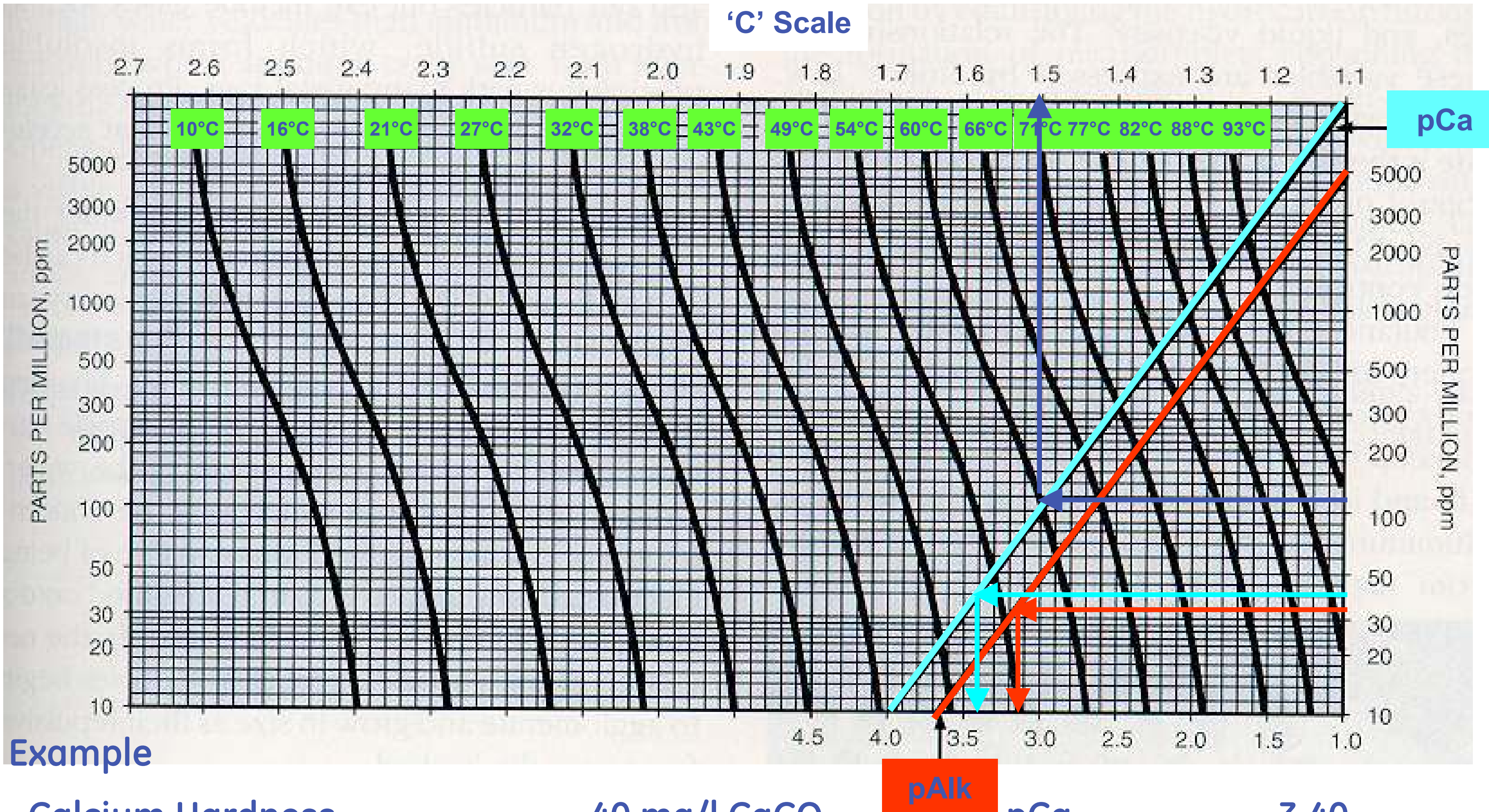


Example

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

$LSI = pH_a - pH_s = -0.95$

RYZNAR STABILITY INDEX

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

RYZNAR STABILITY INDEX

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
		Total (pH_s)	8.05
pH of Cooling Water (pH_a)	7.10	LSI = $pH_a - pH_s$ = -0.95	
		CORROSIVE	
		RSI = $2pH_s - pH_a$ = 9.00	
		CORROSIVE	

POLYPHOSPHATES

- Sensitive to hydrolysis (into oPO_4) depending on :

  temperature (50 - 60°C)
  residence time
  pH in the system

PHOSPHONATES

- *Chelating effect*

Blocks the generation of $CaCO_3$ crystalls

Reduce speed of growth

- *Depending on the type of phosphonate*

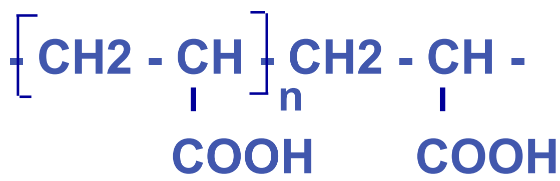
Sensitivity to chlorination (oxidation)

Little to no risk of Ca phosphonate precipitation

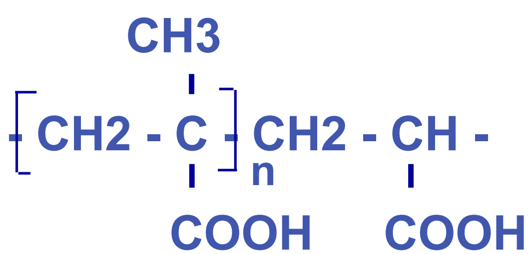
Phosphonate	C mg/l	CONCENTRATION (mg/l)			
		40 °C		80 °C	
		after 1/2 h	after 24 h	after 1/2 h	after 24 h
PBTC	10	10	9	9	8
HEDP	10	9	5	5	1
AMP	10	3	0	1	0

POLYACRYLATES

POLYACRYLATES



POLYMETHACRYLATES



AEC : Alkyl Epoxy Carboxylate

- GE Water & Process Technologies patented technology
- No Phosphorus
- Only contains C, H, O
  - Environmental fiendly
- Formulated with HPS I
  - Totally resistant to Cl_2 et Br_2

Chapter 4.2

CORROSION INHIBITION TREATMENT PROGRAMMES

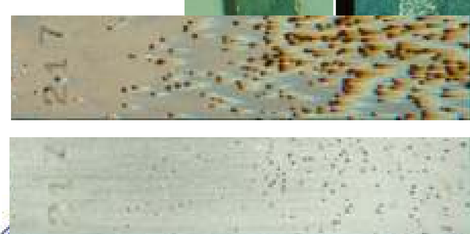
Units of Corrosion Rate

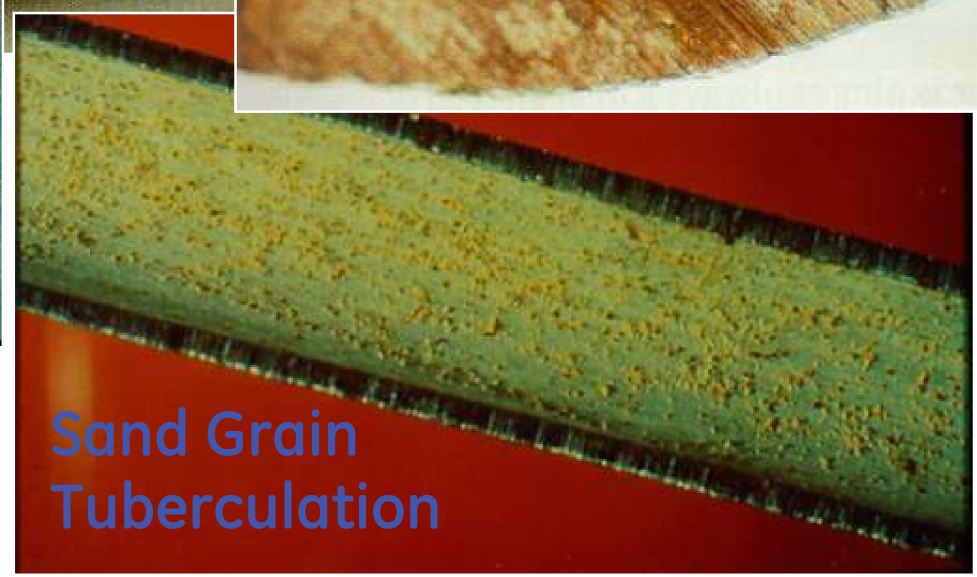
mils per year = 1/1000 inch per year
mm/y = millimetres per year

1 mpy = 0.025 mm/y
1 mm/y = 40 mpy

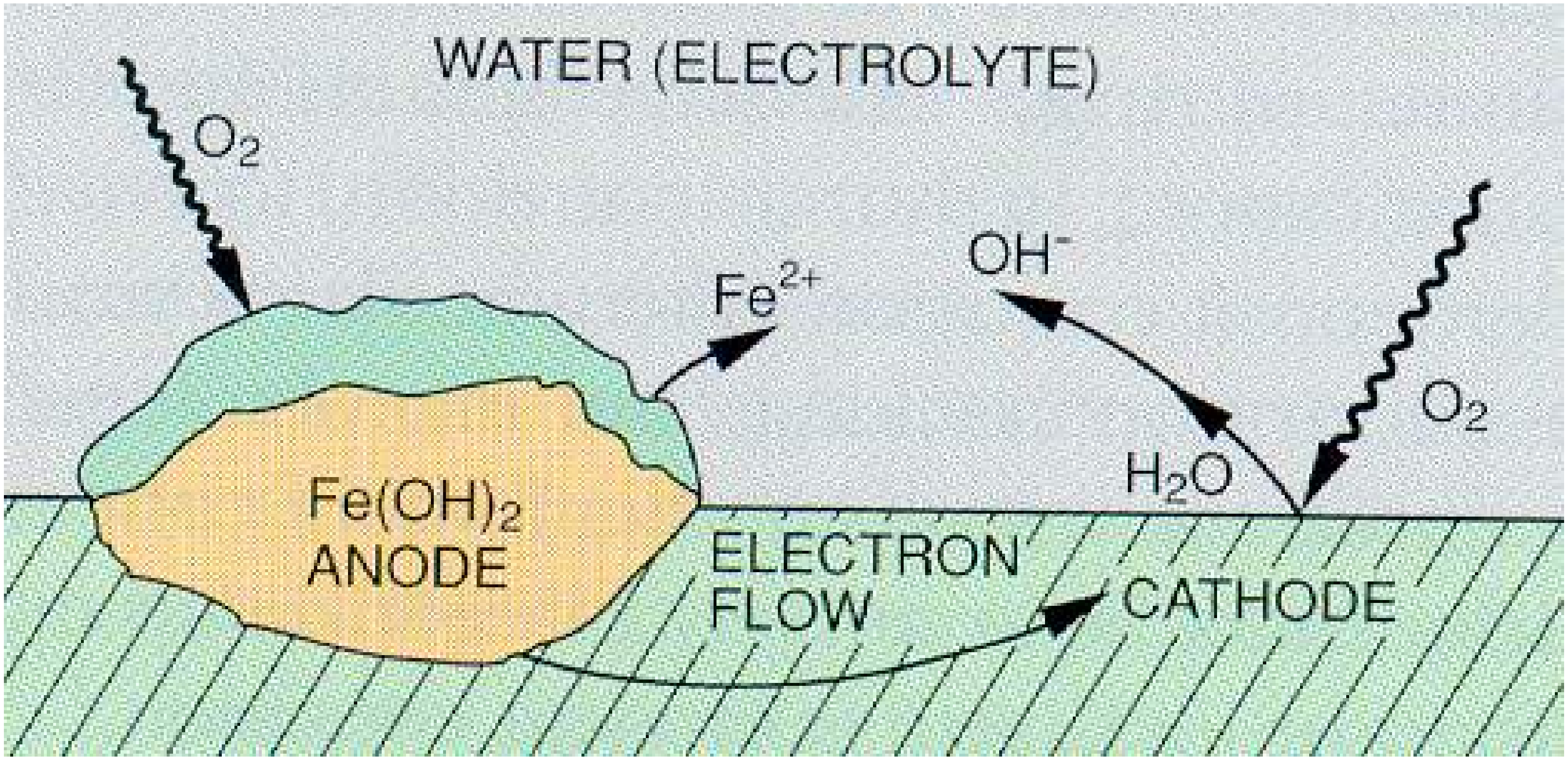
< 4 mpy	0.1 mm/y	Generally regarded as acceptable
< 3 mpy	0.075 mm/y	Good
< 2 mpy	0.05 mm/y	Very good
< 1 mpy	0.025 mm/y	Excellent

Pitting and Tuberculation





Classic Iron Corrosion Cell



Anode reaction

$$Fe^0 \Rightarrow Fe^{++} + e^-$$

Cathode reaction

$$O_2 + 2H_2O + 4e^- \Rightarrow 4OH^-$$

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

$$4Fe(OH)_2 + O_2 + 2H_2O \Rightarrow 4Fe(OH)_3$$

TYPES of CORROSION

Galvanic Corrosion	bi-metallic
Crevice Corrosion /pitting	electrochemical differential aeration chemical
Intergranular Corrosion	attack at the grain joints
Selective Leaching	loss of one metal in an alloy
Erosion Corrosion	mechanical
Stress corrosion cracking	stress + agressivity
(Bacterial)	

GALVANIC CORROSION

When there is an electrochemical potential difference beween two metals immersed in an electrolyte

When these metals are in contact (or if there is an electrical connection), a corrosion cell is created

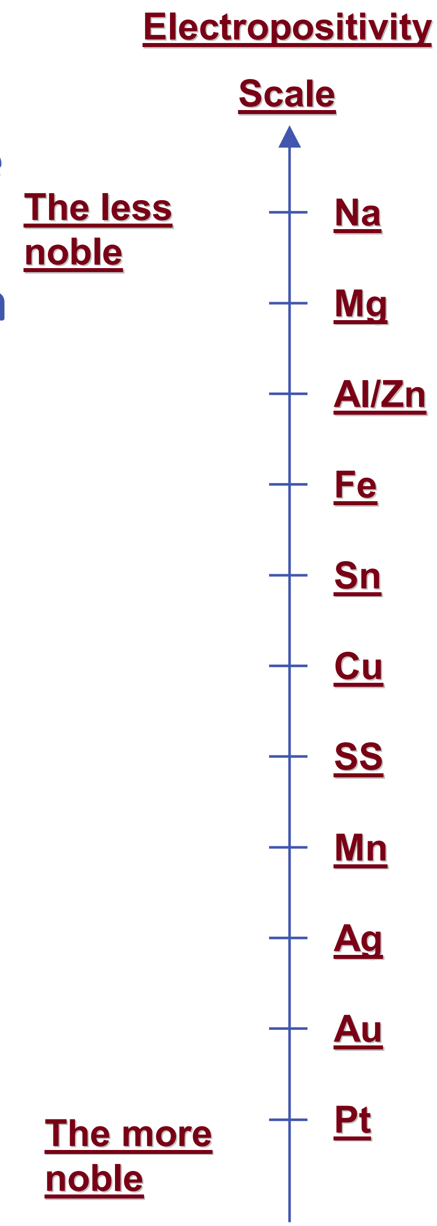
- The more noble metal is the cathode
- The less noble metal is the anode

The more noble metal is protected, more than in the absence of contact (cathodic protection)

The less noble metal is corrodes (anode)

GALVANIC CORROSION

- The corrosion rate will be lower, as the location is more remote end the conductivity is lower
- The corrosion rate will be very high in the ratio between the surface area of the cathode to the anode is high. (Current density)
- The most frequent galvanic corrosions:
  - Steel/Copper
  - Steel/SS
  - Al/Steel
  - Al/SS
  - Al/Copper
- Galvanic corrosion requires
  - A contact between 2 different metals
  - An electrolyte (ambient humidity can be enough)

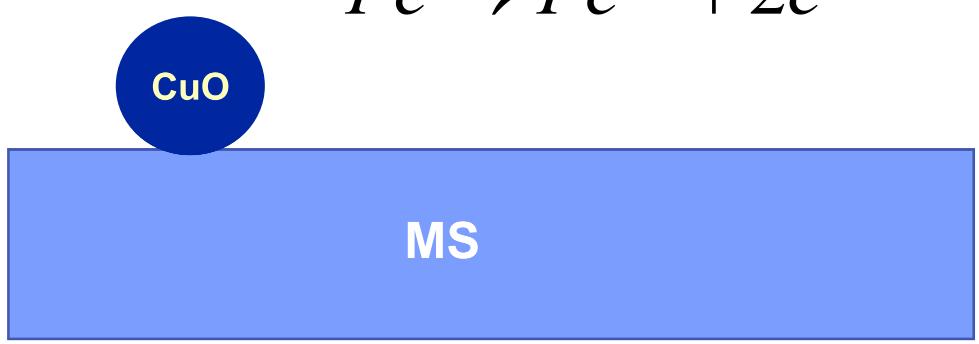


GALVANIC CORROSION

There is a risk for having galvanic corrosion when copper corrosion products deposit on mild teel

$$Cu^{2+} + 2e^{-} \rightarrow Cu$$

$$Fe \rightarrow Fe^{2+} + 2e^{-}$$



DIFFERENTIAL AERATION CORROSION

The electrochemical potential of a metal is in water is driven by the oxygen concentration:

$O_2 + 2e^- + H_2O \Rightarrow 2OH^-$

$E = E°_{O_2 / OH^-} + 0.06/2 * \log [p(O_2) / (OH^-)^2]$

The area under the deposit contains less oxygen than the one at the surface in the vicinity ($p(O_2)$ under deposit < $p(O_2)$ outside deposit), Therefore the electrochemical potential under the deposit is lower.

A corrosion cell is created where the anodic part is under the deposit d (lower potential)

Any deposit (organic or inorganic) can generate this process and create under deposit corrosion.

PITTING CORROSION

Very localised corrosion

The most dangerous Type of corrosion

> Difficult to detect: the metal loss is very limited
> Damageable: lead to heat exchanger leakages

A pit is a very active anodic zone

The corrosion process is identical to the one for crevice corrosion.

The pit protects cathodicly the bulk of the metal surface.

The reaction can start due to:

> Defect in the metal
> Erosion

EROSION CORROSION

Mechanical attack due to:

- Solids
- Too high fluid velocity
- Cavitation

Can be easily identified because there is a visible pattern (like waves) and the metal surface is clean.

All metals can be subject to erosion corrosion. The most sensitive parts are elbows, T pieces, valves, pumps, eductors and spraying equipments…

Causes for corrosion

Deposition → underdeposit (supply lines)

Erosion → on elbows weldings for turbulent flow

Microbiological → stagnant anaerobic conditions (little access for biocides)

Favoured by geometry

Manufacturing Defect

Galvanic corrosion?

Deposition on the top caused by grease released under stagnant conditions?

CORROSION INHIBITORS

General mechanism of corrosion inhibitors

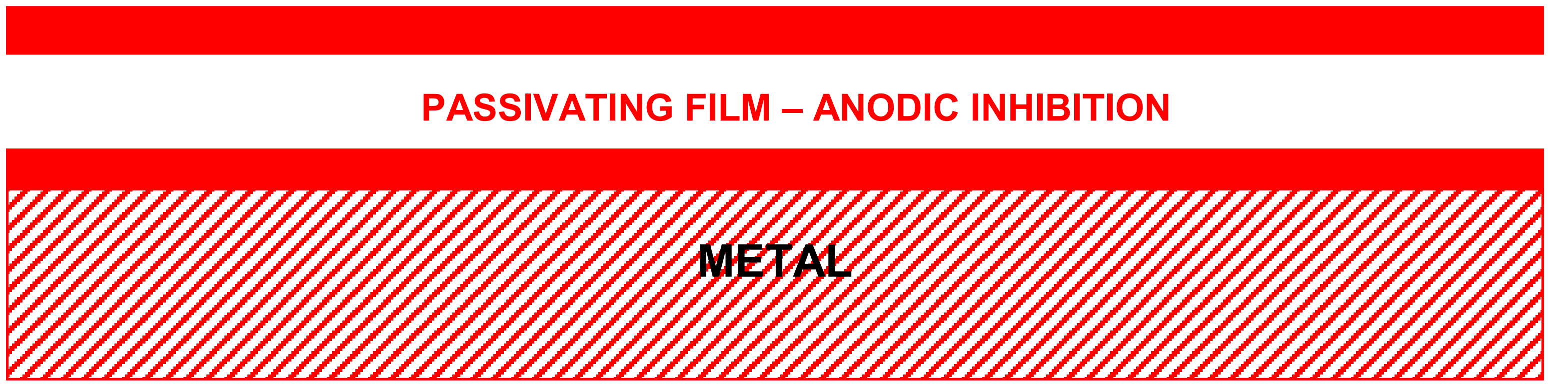
PASSIVATING FILM

> ANODIC INHIBITION
> LOW FOULING TENDENCY
> RESISTANCE TO pH FLUCTUATIONS (REMANENCE)
> VERY THIN (~ 100 A°)

PRECIPITATING FILM

> CATHODIC INHIBITION
> REDUCE PITTING
> REQUIRES ACCURATE pH CONTROL

ANODIC INHIBITION MECHANISM



CrO_4^{2-}

MoO_4^{2-} hc

NO_2^{-}

PO_4^{3-} hc

Na_3SiO_4

Poly PO_4 hc

INHIBITORS

CHROMATES

CrO_4^{2-}

ANODIC INHIBITOR

NO OXYGEN NEEDED (STRONG OXIDANT)

BANNED DUE TO TOXICITY

HIGH CONCENTRATION IF USED ON ITS OWN

SENSITIVE TO REDUCING AGENTS

INHIBITORS

NITRITES

NO_2^-

ANODIC INHIBITOR

OXYGEN NOT NEEDED, EVEN NOT SUITABLE

HIGH DOSE RATE REQUIRED

POSSIBLE BIODEGRADATION

FOR CLOSED SYSTEMS ONLY

INHIBITORS

SILICATES

ANODIC INHIBITORS

ENVIRONMENTAL FRIENDLY

LONG TIME TO ESTABLISH PROTECTION

OXYGEN NOT NECESSARY BUT HIGHER DOSAGE IF NO O_2

INHIBITORS

HIGH CONCENTRATION ORTHOPHOSPHATES

$oPO_4^{3-} > 10$ ppm

ANODIC INHIBITOR

OXYGENE NEEDED

OXIDES FILM PASSIVATION

Ca PHOSPHATES DISPERSANT NECESSARY

NEUTRAL pH CONTROL

INHIBITORS

HIGH CONCENTRATION MOLYBDATES

MoO_4 > 200 ppm

ANODIC INHIBITOR

OXYGENE OR OXYDANT NEEDED

ENVIRONMENTAL FRIENDLY

SENSITIVE TO CHLORIDES

HIGH DOSE RATE (>200 ppm)

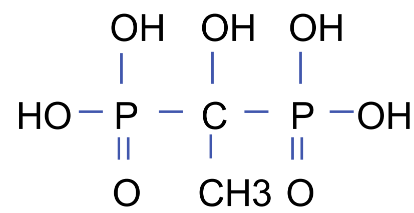
pH FLEXIBILITY

FOR CLOSED SYSTEMS ONLY

INHIBITORS

ORGANIC

PHOSPHONATES (HEDP, AMP)



HEDP

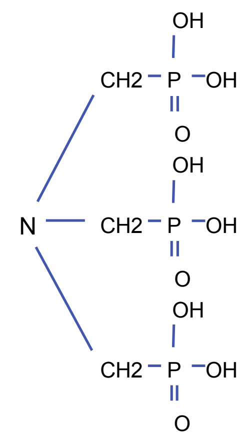
ANODIC INHIBITOR

OXYGENE NEEDED

DOSE RATE CRITICAL (>4,5 ppm)

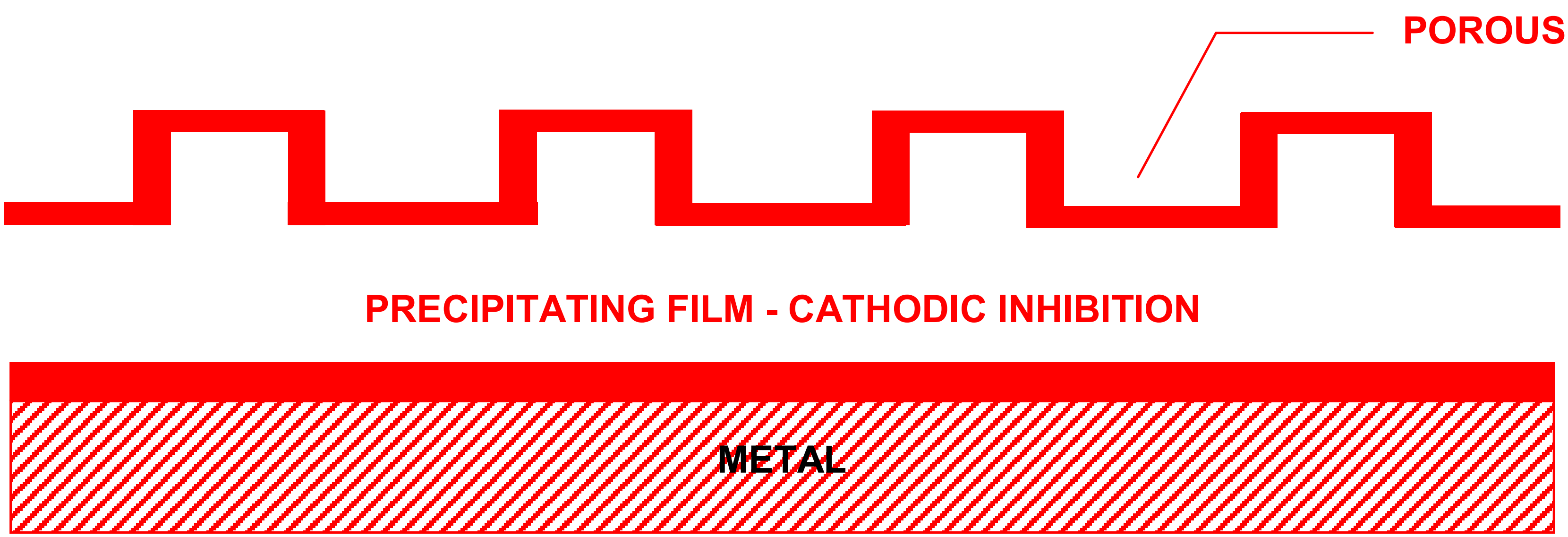
RISK OF PRECIPITATION

HIGH pH



AMP

INHIBITION CATHODIC MECHANISM



$CaCO_3$

$Ca_3 (PO_4)_2$

POLY PO4

ZINC

GE imagination at work

INHIBITORS

ZINC

CATHODIC INHIBITOR

EFFECTIVE AT LOW CONCENTRATION (>1,5 ppm)

USED IN COMBINATION WITH OTHER INHIBITORS

LIMITED LEVEL FOR DISCHARGE

DEPOSITION

INHIBITORS

LOW CONCENTRATION ORTHOPHOSPHATES

CATHODIC INHIBITOR

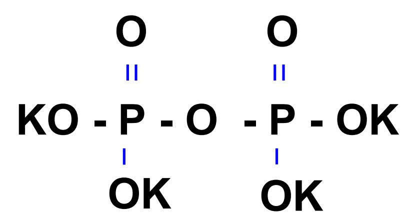
CALCIUM PHOSPHATE FILM

RISK OF FOULING

ALKALINE pH CONTROL

INHIBITORS

POLYPHOSPHATES



pyrophosphate

CATHODIC INHIBITOR

FILM FORMATION

NEUTRAL OR ALKALINE pH CONTROL

POSSIBLE REVERSION TO ORTHOPHOSPHATES
(temperature, residence time)

PHOSPHATE INHIBITORS

DIANODIC

CHROMATE LIKE PERFORMANCE

HAS BECOME AN INDUSTRIAL STANDARD IN MANY PARTS OF THE WORLD

APPLICABLE TO MANY VARIED SYSTEMS AND WATER CHEMISTRIES

MORE THAN TWO DECADES OF EXPERIENCE

DIANODIC

OPERATES AT pH 6.8 to 7.8

MOST APPLICATIONS REQUIRE pH CONTROL

FOR SYSTEMS CONTAINING YELLOW METALS REQUIRES INCLUSION OF AN AZOLE

DIANODIC

Components

ORTHOPHOSPHATE

(high concentration)

CORROSION INHIBITOR

Predominantly Anodic inhibitor

DIANODIC

Components

POLYPHOSPHATE

CORROSION INHIBITOR

- Cathodic inhibitor
- Useful as an inhibitor against pitting

DIANODIC

Components

CALCIUM PHOSPHATE INHIBITOR

> **POLYMER HPS I**

Superior calcium phosphate inhibitor and dispersant for iron and suspended solids

CALCIUM CARBONATE INHIBITOR

HEDP/CAPS

DISPERSANT

DIANODIC

Components

TTA/HRA

YELLOW METAL CORROSION INHIBITOR

> HRA is a GE Betz patented Halogen Resistant Azole

DIANODIC

Programme Mechanism

Anode
80%

$Fe^0 + oPO_4 \longrightarrow$ Passive Iron Oxide layer (mainly magnetite)

Cathode
20%

$Ca + oPO_4 \longrightarrow Ca_3(PO_4)_3$

$Ca + pPO_4$ —— Ca polyphosphate

CONTINUUM

CONTINUUM AT

L.S.I.< +2.5

CONTINUUM AEC

L.S.I.< +2.8 (+3.0)

CONTINUUM AT

AN **EXTENSION** OF DIANODIC TECHNOLOGY TO ALKALINE pH

FOR LOW CALCIUM WATERS AND pH UP TO 8.2, DIANODIC PHOSPHATE LEVELS ARE USED AND POLYPHOSPHATE INCLUDED

FOR HIGHER CALCIUM WATERS THE PREDOMINANT CORROSION INHIBITOR IS BASED ON PHOSPHONATE AND $CaCO_3$

CONTINUUM AT

OPERATES AT pH 7.8 to 9

SOME APPLICATIONS MAY STILL REQUIRE pH CONTROL

FOR SYSTEMS CONTAINING YELLOW METALS REQUIRES INCLUSION OF AN AZOLE

CONTINUUM AT

Components

- Organic phosphate
- Ortho-phosphate
- Polymer HPS
- Azole

CONTINUUM AT

Programme Mechanism

Alkaline AEC phosphate treatment

inorganic PO_4
Calcium Carbonate Inhibitor (AEC)
Calcium Phosphate Inhibitor (Copolymer)
pH = 8.0 - 9.5

20 % ANODE

80 % CATHODE

Passivation

$Fe^0 + oPO_4 \rightarrow Fe_3O_4$

Precipitation

$Ca + CO_3 \rightarrow CaCO_3$

$Ca + oPO_4 \rightarrow Ca_3(PO_4)_2$

CONTINUUM AEC

Components

ORTHOPHOSPHATE

CORROSION INHIBITOR

Anodic and Cathodic inhibitor

Predominantly Anodic at Low Hardness and Low Range pH

Cathodic at High Hardness and High range pH

CONTINUUM AEC

Components

DTPMP

CORROSION INHIBITOR

Primarily as a source of **oPO4** in halogenated systems (included for formulation reasons)

It can be a corrosion inhibitor in it's own right

CONTINUUM AEC

Components

AEC

CALCIUM CARBONATE INHIBITOR

Non Phosphorous, non Phosphonate Calcium Carbonate Inhibitor

Tolerant to high Chlorine concentrations

High Calcium tolerance

CONTINUUM AEC

Components

POLYMER HPS I

Superior calcium phosphate inhibitor and dispersant for iron and suspended solids

DISPERSANT

CONTINUUM AEC

Components

HRA

YELLOW METAL CORROSION INHIBITOR

HRA is a GE Water & Process Technologies patented Halogen Resistant Azole

CONTINUUM AEC

Components

MOLYBDATE

TRACER

Concentrations typically too low to be an effective corrosion inhibitor

CONTINUUM AEC

How much PO4 is required ?

- depends on Ca and pH

How much AEC is required ?

- 6 to 8 mg/l active for CaCO3 inhibition

How much polymer is required ?

- depends on Ca and pH and PO4

CONTINUUM AEC

Various ratios of polymer to AEC required to cover a range of conditions:

- 100 to 1,200 mg/l Ca
- pH (7.0) 7.8 to 9.5
- (0) 2 to 8 (20) mg/l oPO4
- (top off: 0.5 to 2.5 mg/l Zn)

Benefits of CONTINUUM AEC

Benefits of Continuum AEC

> Wide range of waters and systems can be treated
> Wide range of programmes or approaches available
> Wide range of products to cater for the wide range of applications, waters and approaches

Limitations of Continuum AEC

High Fe

High suspended solids

High temperatures

> Create additional polymer demand which may be accomodated with higher polymer concentrations up to a given limit which depends on system design and operation

Comparative Phosphates Programme Guidelines

	DIANODIC II	CONTINUUM AT	CONTINUUM AEC	
pH	(6.8) 7.0 - 7.8	(> 7.8) 8.2 - 9.0	(> 7.8) 8.2 - 9.0 (9.5)	LSI $MgSiO_2$ $CaMgSiO_2$
Calcium	(35) 100 - 1200	(75) 100 - 1200	(100) 250 - 1200	mg/l $CaCO_3$
max LSI	N/A	+ 2.5	+ 2.8 + 3.0	Industrial Systems Low Heat, High Flow
max t °C	65 °C	60 °C	70 °C	Depends on exchange and velocity
Iron	< 3 mg/l Fe	< 5 mg/l Fe	< 10 mg/l Fe	Theoretical cycled MU mg/l Fe
Reactive Silica	< 200 mg/l SiO_2	< 200 mg/l SiO_2	< 200 mg/l SiO_2	max SiO_2 defined by $MgSiO_2$ $CaMgSiO_2$

Conductivity < 6000 $\mu S\ cm^{-1}$ Chloride < 1500 mg/l Cl Sulphate < 2500 mg/l SO_4

ALKALINE ZINC
AND
ZINC PHOSPHATE INHIBITORS

Zinc Programmes

Cathodic inhibitor

Used on its own or in conjunction with phosphate

Neutral to alkaline control range

Some potential discharge concerns

ZINC BASED PROGRAMMES

PRECIPITATING PROGRAMME

> ZINC PHOSPHATE DOES NOT DEPEND UPON CALCIUM FOR FILM FORMATION

> FILM FORMATION A FUNCTION OF ZINC SOLUBILITY WITH pH

> POLYMERS CONTROL POTENTIAL FOR BULK WATER PRECIPITATION OF ZINC AND CALCIUM PHOSPHATE

ZINC PHOSPHATE TREATMENT

Zn
inorganic PO_4
[Zinc Phosphate Inhibitor (Copolymer)]
pH 7.0 - 8.5

10 % ANODE

90 % CATHODE

Passivation

$Fe^0 \rightarrow Fe_3O_4$

O_2 / PO_4

Precipitation

Zn + $oPO_4 \rightarrow Zn_3(PO_4)2$

Ca + $oPO_4 \rightarrow Ca_3(PO_4)_2$

ZINC PHOSPHATE TREATMENT

Components

ZINC

CORROSION INHIBITOR

> Cathodic Inhibitor

ZINC PHOSPHATE TREATMENT

Components

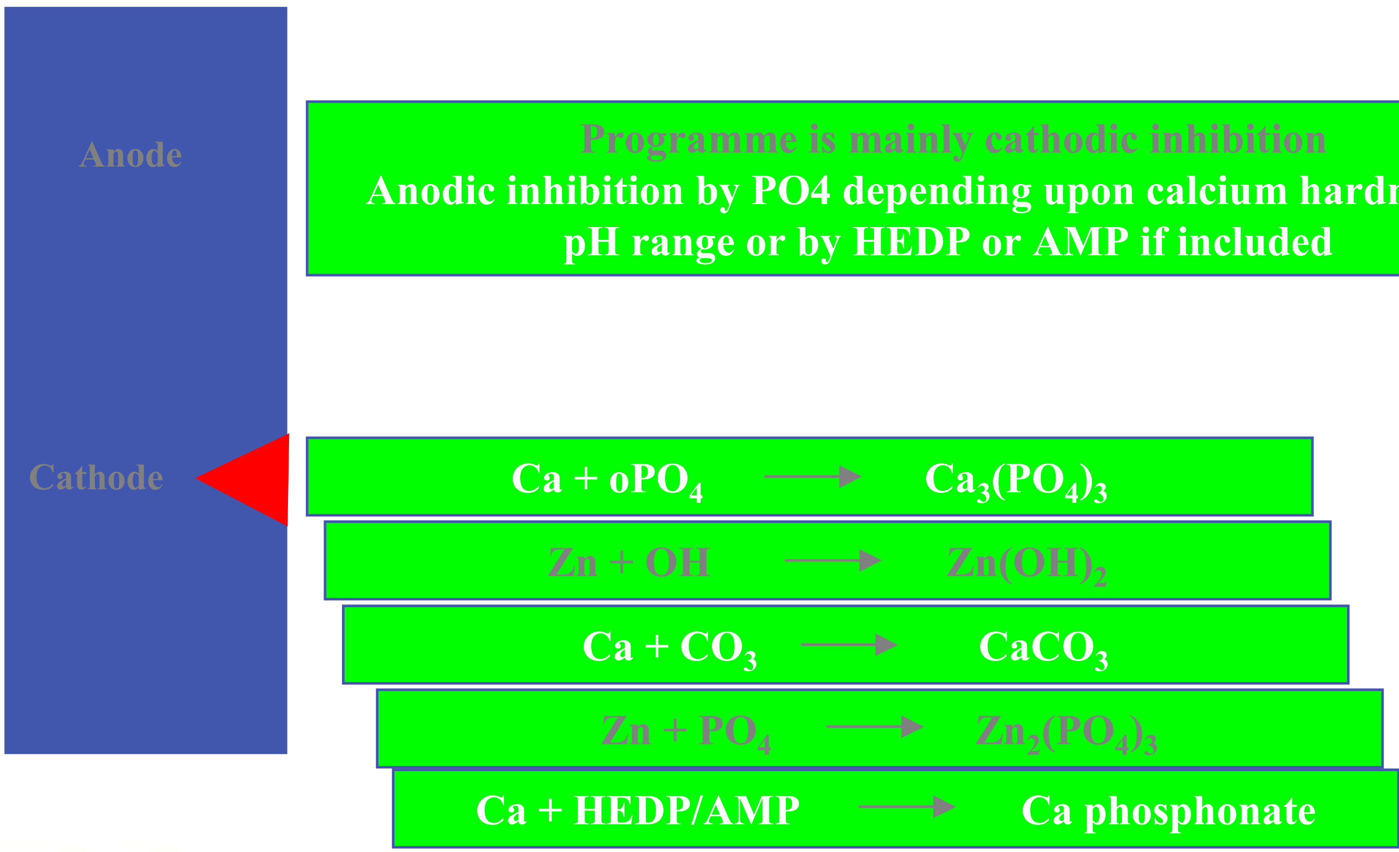
ORTHOPHOSPHATE

CORROSION INHIBITOR

> Cathodic inhibitor

ZINC PHOSPHATE TREATMENT

Programme Mechanism



GE imagination at work

ZINC ORGANIC TREATMENT

L Zn
Organic Phosphate
[Zinc Phosphate Inhibitor (Copolymer)]
pH 8 - 9

30 % ANODE

70 % CATHODE

Passivation

Fe^0 → Passive Film

Organic PO_4

Precipitation

$Ca + CO_3$ → $CaCO_3$

Ca + Phosphonate → Ca (Phosphonate)

$Zn + OH_4$ → $Zn(OH)_2$

ZINC ORGANIC TREATMENT

Components

HEDP and AMP

CALCIUM CARBONATE INHIBITOR

CORROSION INHIBITOR

> at concentrations above 4.5 mg/l PO4

ZINC ORGANIC TREATMENT

Components

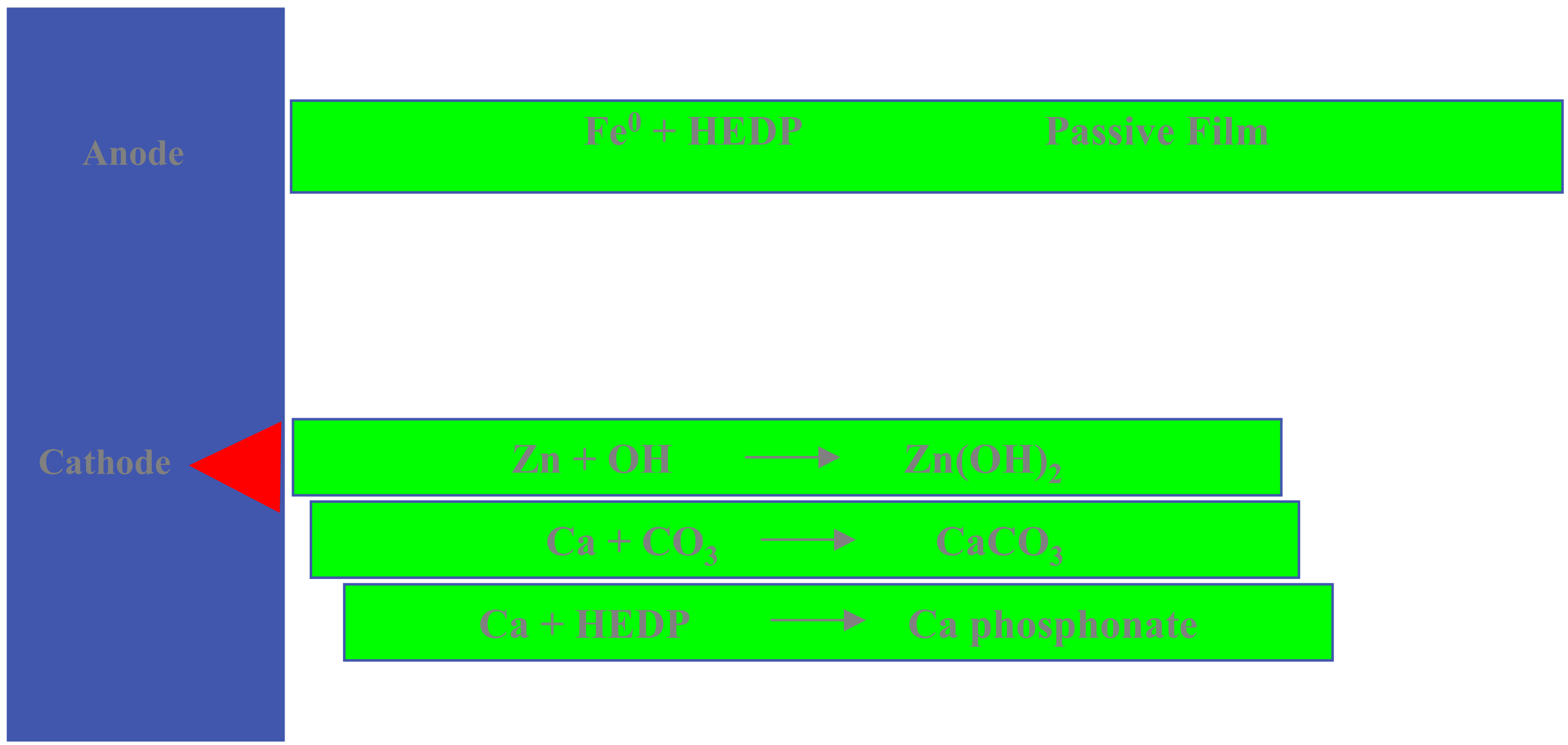
POLYMER (HPS II/HPS I)

- **INHIBITOR FOR**
- CALCIUM PHOSPHATE
- ZINC HYDROXIDE & PHOSPHATE
- CALCIUM PHOSPHONATE
- CALCIUM CARBONATE

- DISPERSANT FOR
- Iron and suspended solids

ZINC ORGANIC TREATMENT

Programme Mechanism (Alkaline Zinc)



Low Hardness Waters

Calcium < 100 mg/l $CaCO_3$ difficult to treat effectively particularly if Cl and/or SO_4 is high

- > lack of cathodic inhibition
  - – pitting
- > approaches
  - – high PO_4
  - – **$Zn_3(PO_4)_2$ or Zn (top off)**
  - – high MoO_4
  - – Silicate
  - – Nitrite

Molybdate Programmes

Primarily an anodic inhibitor

Used at high levels in closed systems

Used at low levels in open systems

Neutral to alkaline control range

Does not require hardness

Requires oxygen

Low toxicity

MOLYBDATE TREATMENT

MoO_4
phosphonate
Calcium Carbonate Inhibitor (Phosphonate and PMA)
pH 8 - 9

30 % ANODE

70 % CATHODE

Passivation

$$Fe^0 + MoO_4 \xrightarrow[\text{Organic } PO_4]{O_2} Fe_3O_4 - MoO_4$$

Precipitation

$$Ca + CO_3 \rightarrow CaCO_3$$

$$Ca + \text{Phosphonate} \rightarrow Ca\,(\text{Phosphonate})$$

Chapter 4.3

YELLOW METAL CORROSION INHIBITION TREATMENT PROGRAMMES

GE imagination at work

Yellow Metal Corrosion Inhibition

GE imagination at work

COPPER CORROSION

Aggravating factors are :

- pH
  - In any case it should be >7
  - The best range is between pH 8 and pH 8.5
- Oxidants : Copper is very sentitive to strong oxidants (hypochlorite, H_2O_2, bromine)
- High level of chlorides (less sentive than SS however)
- H2S, CN, NH_3
- Stagnancy (or low water velocity)

GE imagination at work

Inhibition of Yellow Metals by Azoles

Cupric Oxide

Cuprous Oxide

Copper Metal

Uninhibited

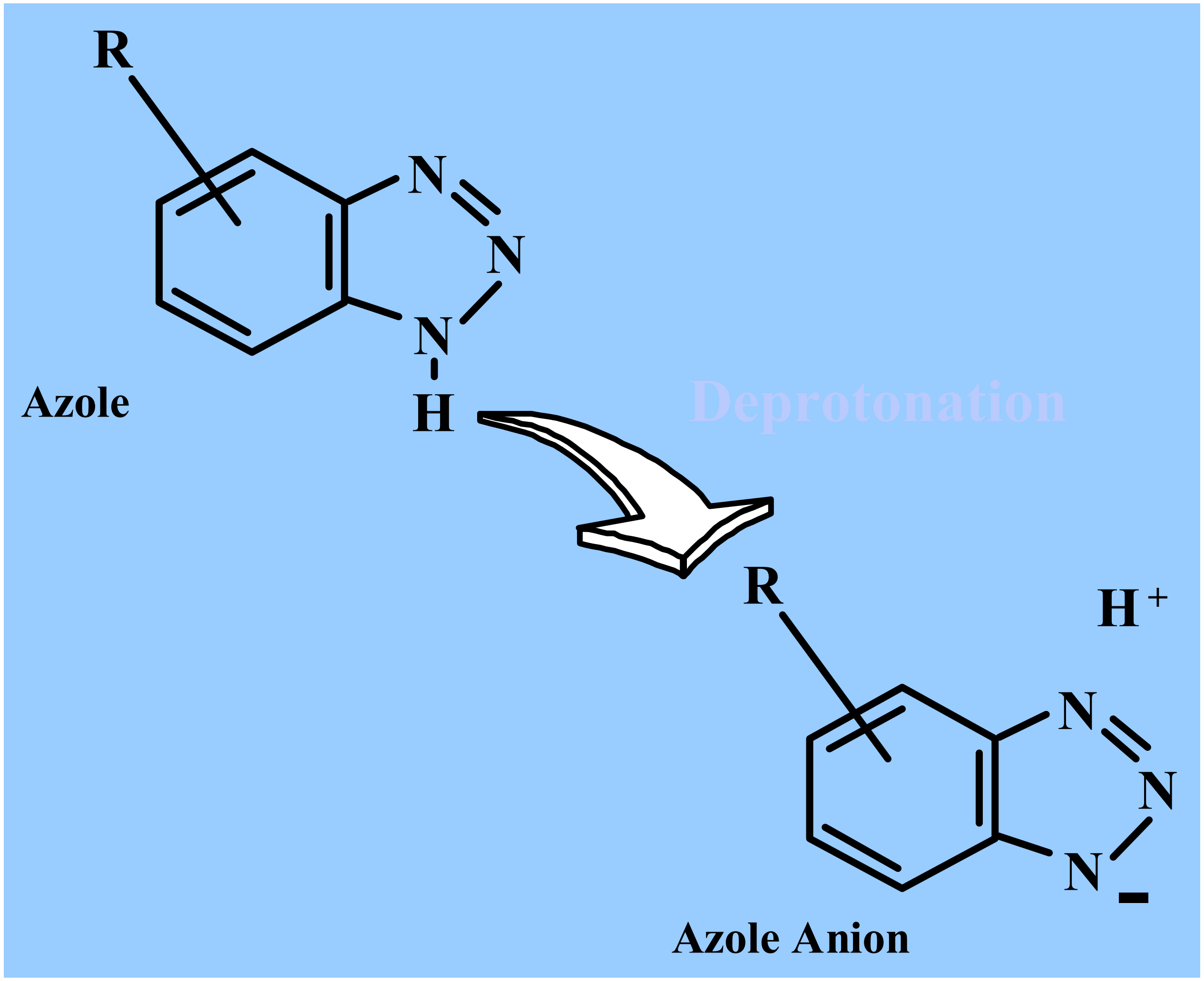
Cu^{I} / Azole Inhibitor Film

Cuprous Oxide

Copper Metal

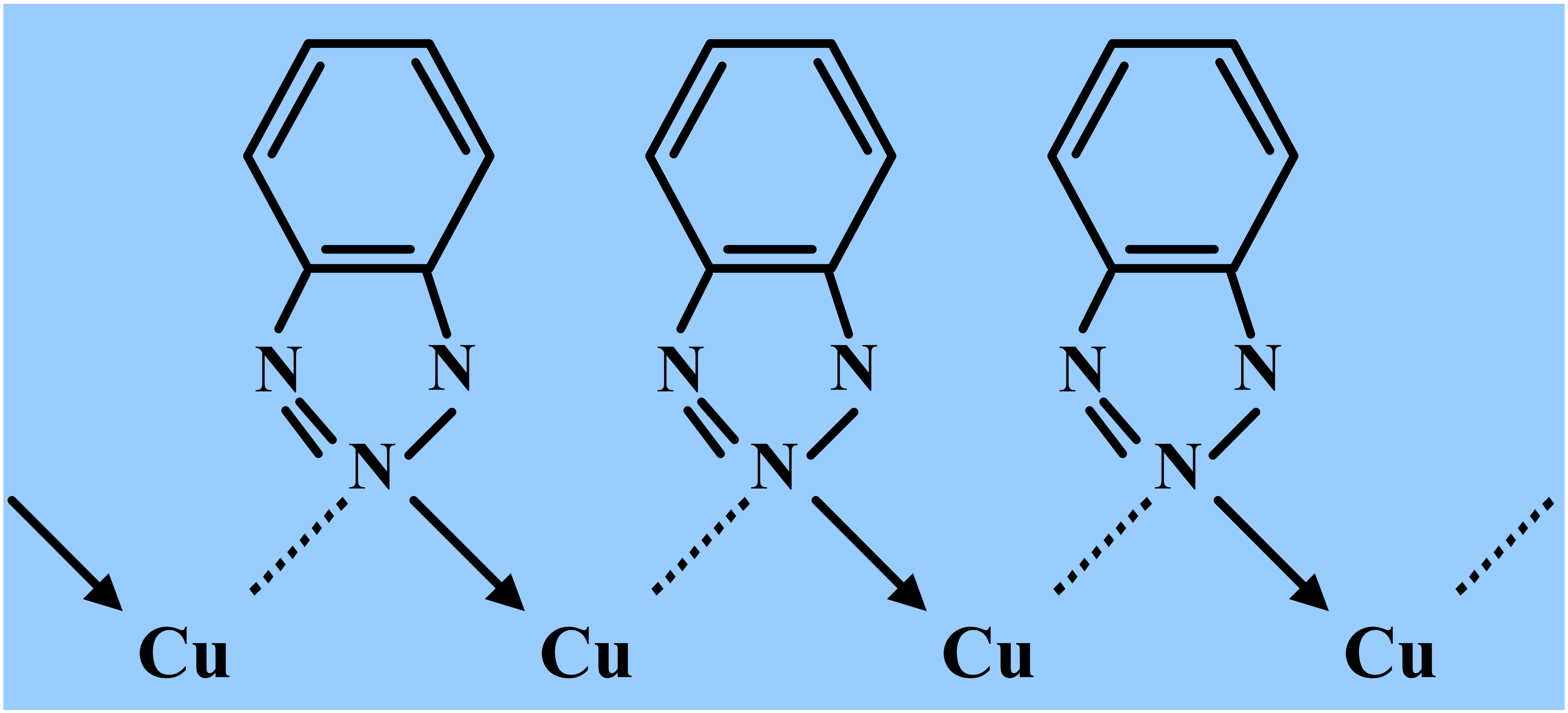
Inhibited

Yellow Metal Corrosion Inhibition



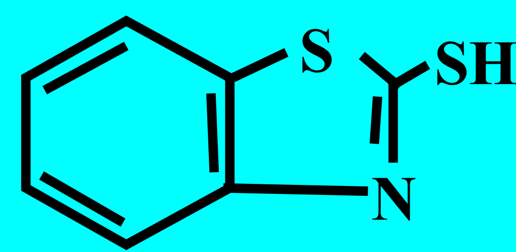
Yellow Metal Corrosion Inhibition

Bridging by Copper Ions

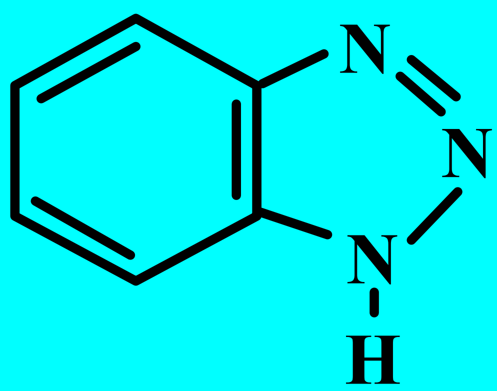


Azoles (TTA, BZT, MBT)

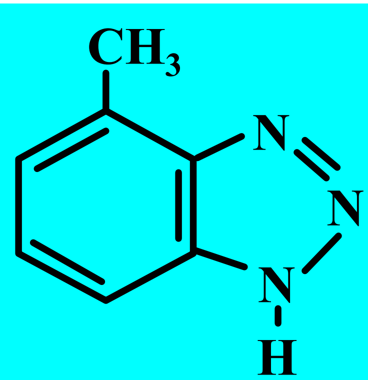
- **Adsorbed films**
- **Used primarily for copper / copper alloy protection**
- **Fed on a continuous basis**



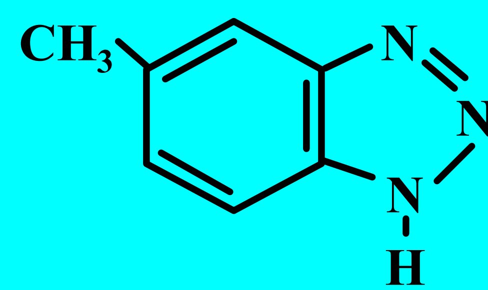
Mercaptobenzothiazole (MBT)



Benzotriazole (BZT)



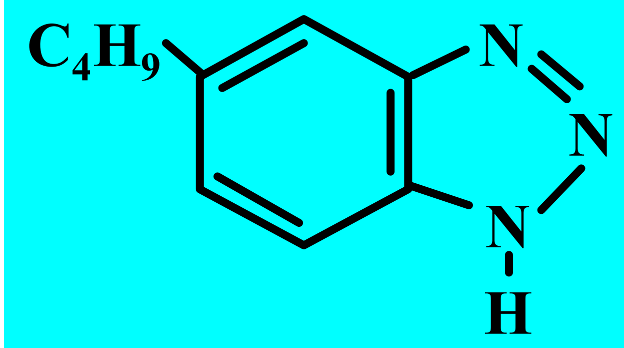
4-methylbenzotriazole (TTA)



5-methylbenzotriazole (TTA)

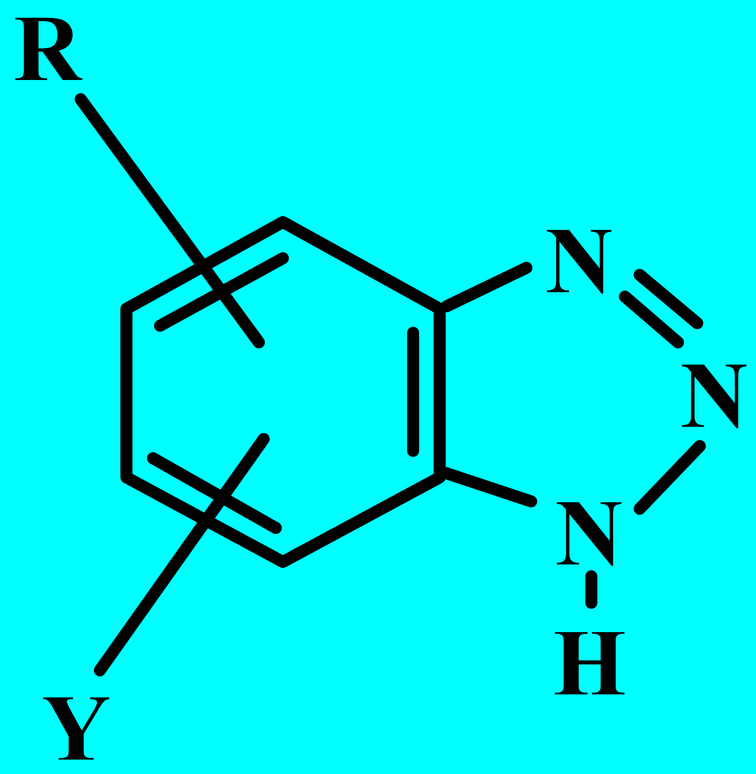
Azoles (bBZT)

- **Fed on an intermittent basis**



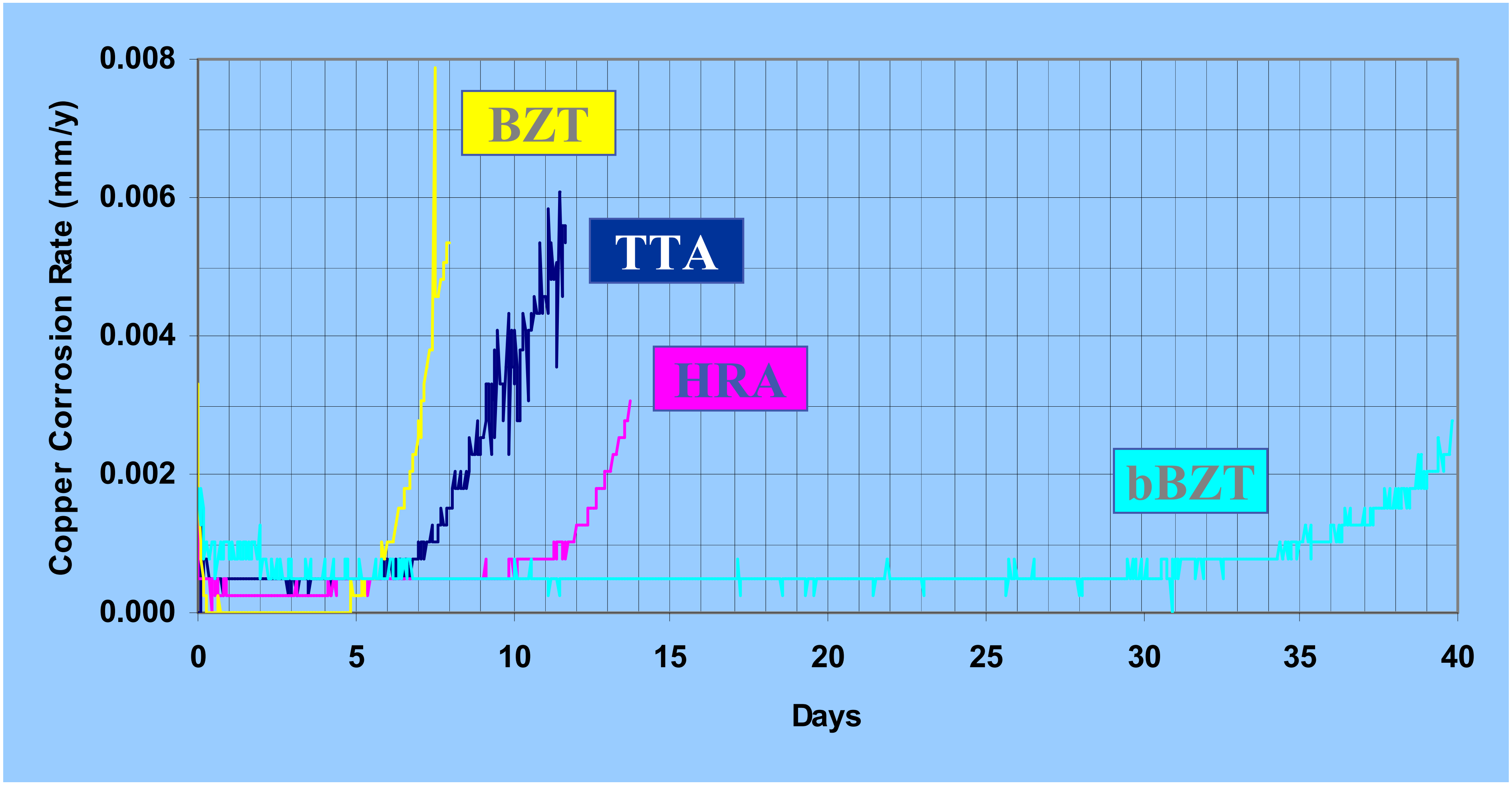
Butylbenzotriazole (bBZT)

Chemical Structure of Azoles



Halogen Resistant Azole (HRA)

Persistency of Azole Films



Chapter 4.4

CLOSED SYSTEM CORROSION INHIBITION TREATMENT PROGRAMMES

Closed System Inhibitors

Nitrite based
CorrShield NT Series

Nitrite

Promotes anodic films

No oxygen required - generally used in closed systems

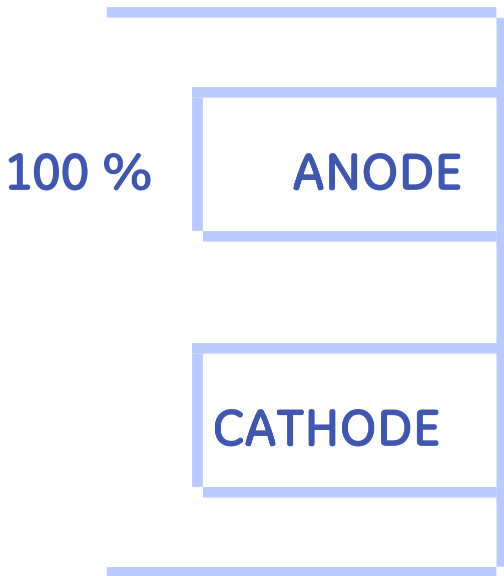
Used at high levels

Susceptible to biodegradation

Affected by Halogens

NITRITE TREATMENT

600 - 1200 mg/L NO_2
pH 7 - 9.5



Passivation

$$Fe^0 + NO_2 \rightarrow Fe_3O_4$$

CorrShield NT Series

	mg/l	NO_2					
NT4201	3000 - 6000	600 - 1200	TTA				
NT4290	20000 - 40000	600 - 1200					
NT4292	2250 - 4500	600 - 1200					
NT4293	8000 - 16000	600 - 1200	MBTZ	PAA	NO_3	SiO_2	Borate

Compatibility
All NT products are compatible with Alcohol and Glycol
NT4293 is not compatible with NaCl or $CaCl_2$ Brines
Others are compatible with NaCl and $CaCl_2$ Brines
If Al present keep pH < 8

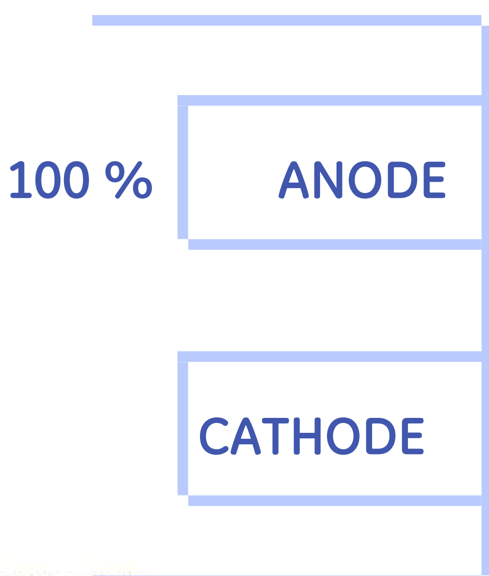
Closed System Inhibitors

Molybdate based
CorrShield MD Series

GE imagination at work

MOLYBDATE TREATMENT

200 - 300 mg/L MoO_4
Calcium Carbonate Inhibitor (PAA)
pH 7.5 - 9.5



Passivation

$$Fe^0 + MoO_4 \xrightarrow[O_2]{} Fe_3O_4 - MoO_4$$

CorrShield MD Series

	mg/l	MoO_4	NO_2				
MD4100	2400 - 3600	200 - 300	160 - 240	PAA	TTA		
MD4101	2300 - 4600	100 - 200		PAA	TTA	Morpholine	
MD4103	1000 - 3000	200 - 600		PAA	TTA		
MD4151	2000 - 6000	200 - 600		PAA	TTA		
MD4152	300 - 1200	25 - 100		PAA	TTA	SiO_2	PBTC
MD4153	600 - 2400	100 - 400					
MD4154	2400 - 3600	70 - 100	200 - 300	PAA	TTA		

Compatibility
All MD products are compatible with Alcohol and Glycol
Not compatible with NaCl or $CaCl_2$ Brines
If Al present keep pH < 8

Closed System Inhibitors

Organic based

CorrShield OR Series

CorrShield OR Series

	mg/l	HPA as PO_4				
OR4400	2000 - 4000	17 - 34	HPS I	TTA	Triazine	pH 8 - 10 Control on Organic PO_4
OR4411	2000 - 4000	17 - 34	HPS I	TTA	Triazine	
DE9886	2000 - 4000	17 - 34	HPS I		Triazine	

Compatibility

Above products are compatible with Alcohol and Glycol

Not compatible with NaCl or $CaCl_2$ Brines

Specifically Designed for $CaCl_2$ Brine		HPA as PO_4	
OR4401	12000 - 18000	240 - 360	HPS I

Low conductivity programme		DEHA		
OR4410	50 - 100	5 - 10	BZT	Cyclo

If Al present keep pH < 8

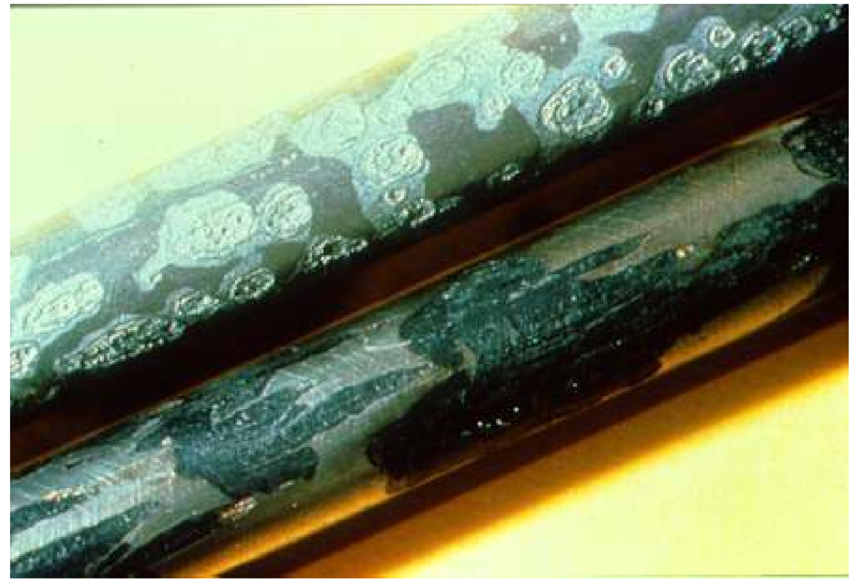
Chapter 5

MICROBIOLOGICAL CONTROL

Microbiological Control

Bacteria

- Slime forming
- Sulfate reducing
- Nitrifying
- De-nitrifying
- Iron Bacteria
- Sulfur Bacteria



Factors Affecting MB Growth

Water quality

Temperatures

pH range

Nutrients

- Sources of C, N, P

Classification

Aerobic Bacteria	Anaerobic Bacteria	Fungi	Algae
Gelatinous or Filamentous pH 4 - 8.5	Often Black pH 4.0 - 10.0	Rubbery or Filamentous pH 2.0 - 7.5	Green or Brown Filaments pH 5 - 8.5

Algae

Pioneer colonisers

Photosynthetic

Grow in sun light areas of tower

CO_2 “fixers”

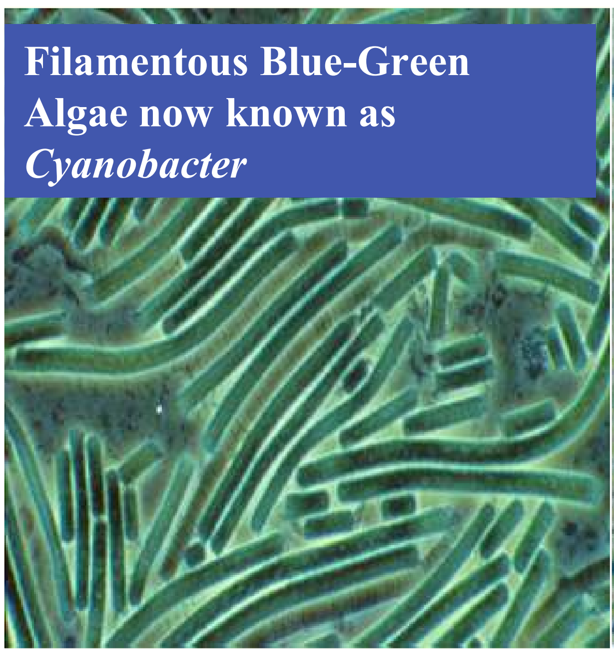
Problems caused

Block distribution nozzles

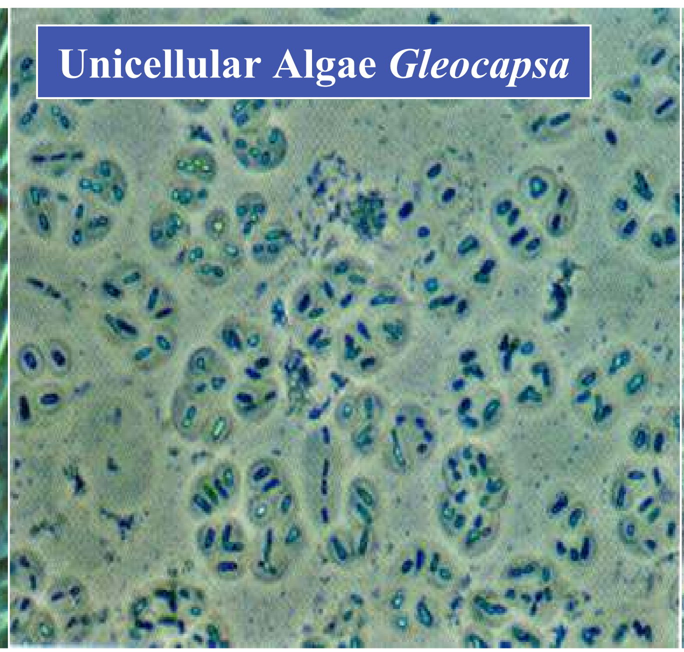
Plug screens

Increase halogen demand

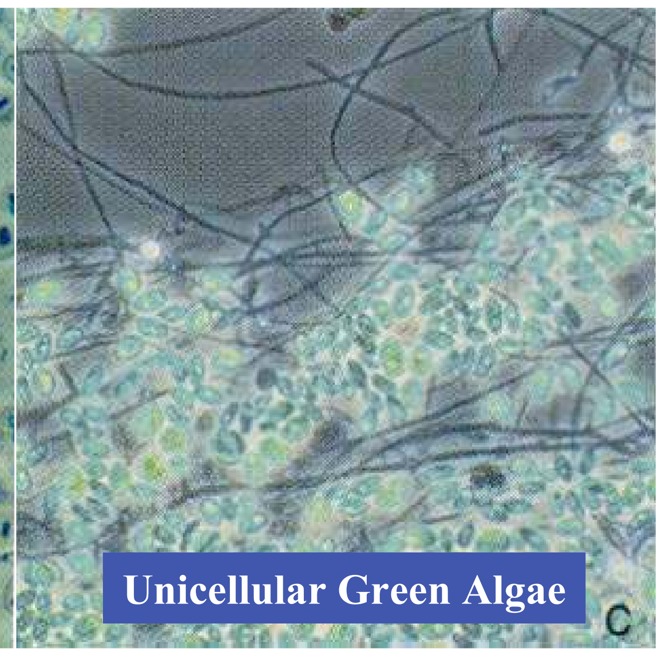
Foster growth of other organisms



Filamentous Blue-Green Algae now known as *Cyanobacter*



Unicellular Algae *Gleocapsa*

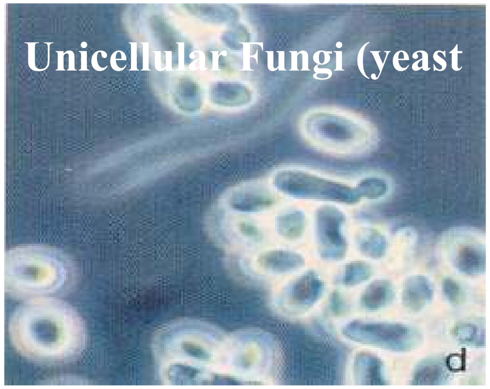


Unicellular Green Algae

Fungi

Plant-like organisms but lack chlorophyll

major forms :



- **Molds - filamentous**
- **Yeasts - unicellular**

Can attack tower wood

- **Brown rot - cellulose degraded**
- **White rot - lignin and cellulose degraded**

Microbiological Control

Oxidising Biocides

> Indiscriminate oxidation

Non-Oxidising Biocides

> Specific Reactions

OXIDISING Vs NON-OXIDISING BIOCIDES

OXIDISING	NON-OXIDISING
non-specific	specific mode of action
react also with suspended solids and organic matter	organisms may acclimatise to the biocide
halogenated by-products may be formed	more expensive

Oxidising Biocides

Chlorine gas
Sodium hypochlorite
Calcium hypochlorite
Chlorine dioxide
Solid halogen donors
Activated Bromide
Peracetic Acid
Ozone

Non-Oxidising Biocides

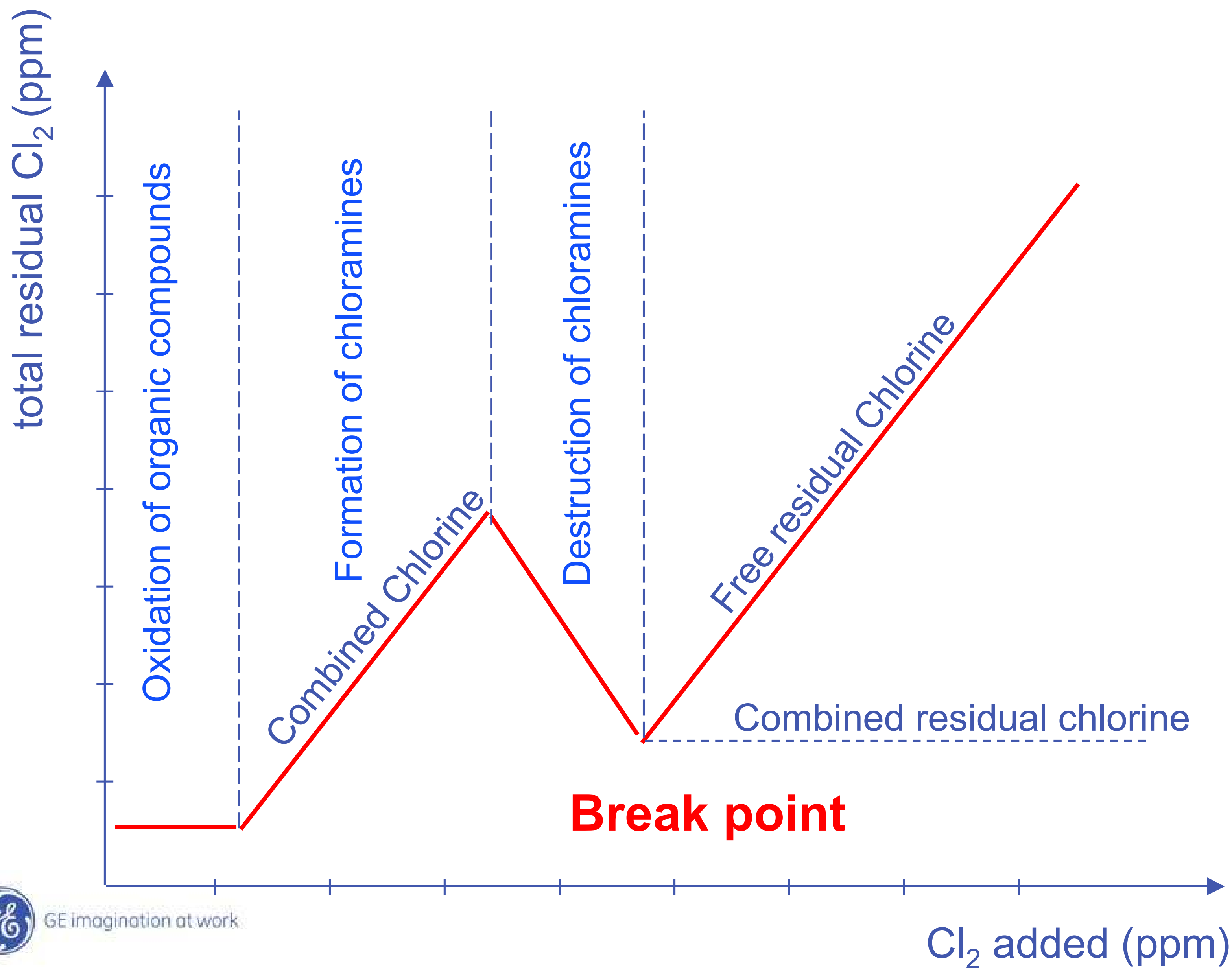
Metabolic Inhibitors

> Bromonitrostyrene (BNS)
> Methylene bisthiocyanate (MBT)
> Dodecylguanidine hydrochloride (DGH)
> Isothiazolin (ISZ)
> Bromo-nitropropane-diol (BNPD)
> Triazines (TBZ) (photosynthesis blockers)
> Dibromo-nitrilo propionamide (DBNPA)

Surface Active Agents (membrane disrupters)

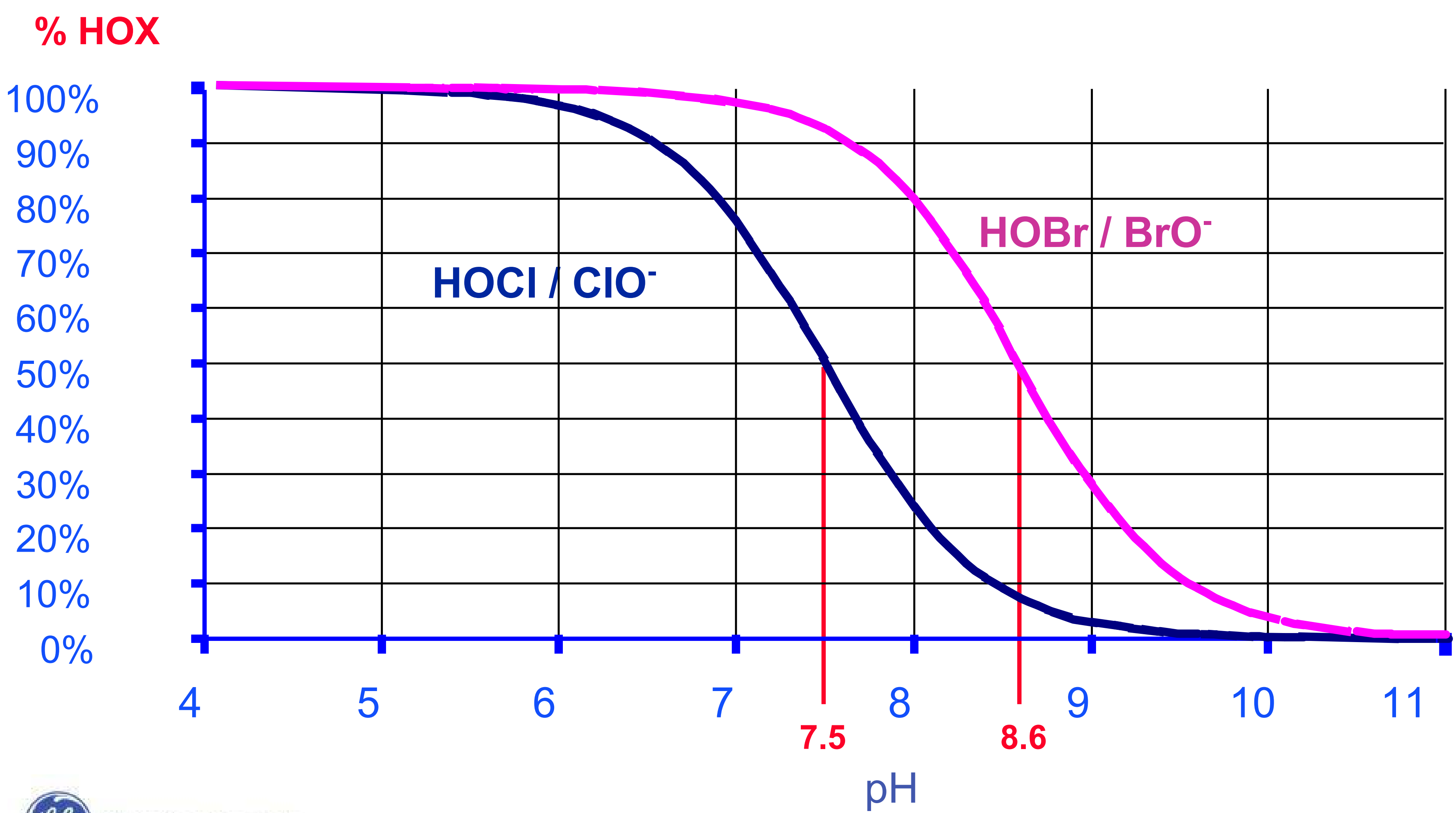
> Quaternary ammonium salts (Quats)
> Dodecylguanidine Hydrochloride (DGH)
> Cocodiamine

BREAK POINT



GE imagination at work

PRE-EMINENCE OF THE IONISED AND NON IONISED SPECIES



GE imagination at work

ACTIVE FORM VS. PH

pH	% HOCl	% HOBr	HOBr / HOCl
6	97	100	
7	76	98	
7,5	50	94	1,9 / 1
8	24	83	3,5 / 1
8,5	9	60	6,7 / 1
9	3	33	11 / 1

50 % HOCl - 50 % ClO^- pH 7,5

50 % HOBr - 50 % BrO^- pH 8,6

REACTION WITH NITROGEN COMPOUND

$HOX + NH_3$ ----- $NH_2X + H_2O$

$HOX + NH_2X$ ----- $NHX_2 + H_2O$

$HOX + NHX_2$ ----- $NX_3 + H_2O$

WITH Cl	WITH Br
NH_2Cl $NHCl_2$ NCl_3	NH_2Br $NHBr_2$ NBr_3

REACTION WITH NITROGEN COMPOUND

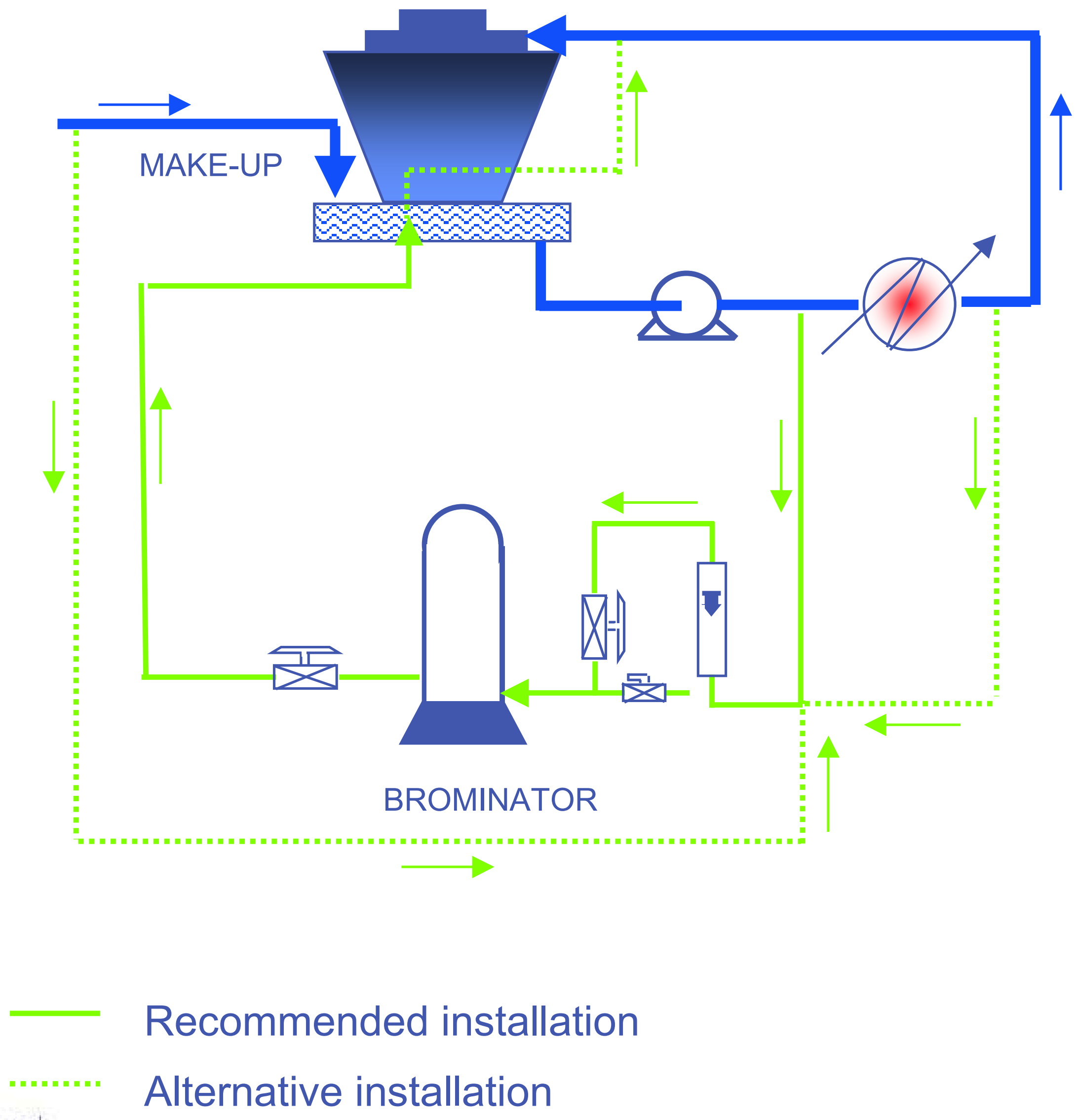
Ex : pH 8

Br	Cl
HOBr 90 %	HOCl 19 %
BrO^- 10 %	ClO^- 81 %

PRODUCTS FORMED

WITH Cl	WITH Br
NH_2Cl 100 %	NH_2Br < 10 %
HOCl 0 %	HOBr 82 %
ClO^- 0 %	BrO^- 8 %

BROMINATOR INSTALLATION



GE imagination at work

Biocide Enhancement

Non-Oxidising Biocide Feed Point

- Highly mixed areas at front end of tower basin
- Physically separate feedpoint of biocides and polymeric dispersant (oxidisers and non halogen stable chemicals - phosphonates - azoles)
- Satellite feed biocide(s) to critical equipment prone to MB fouling
- Feed to hot return to control slime on fouled decks and fill

Biocide Enhancement

Physical Methods

Time of Day

Algaestats

- Peak daylight hours

Biocides (halogens) which are not UV-stable

- Feed at night to minimise photo degradation

Feed Duration

Shot Feed over a short time period

High levels of free halogen will accelerate corrosion

Biocide Enhancement

Chemical Methods

Bio-Surfactants

> Improve penetration of biocide into biofilm
> Increase transport of biocide into cell
> Interfere with cell attachment mechanisms
> Reduce biocide demand.
> Removes biofilms from

Biocide Enhancement

Chemical Methods

Feeding Bio-Surfactants

> **Effective with oxidising and non-oxidising biocides**
> **Compatible with free halogen residuals**
> Once-through or recirculation systems
> **Intermittent**
> - High levels
> **Continuous**
> - Low levels

GE Betz
Spectrus BD1550

“Environmentally friendly” biodegradable biodispersant for biofilm removal and control in industrial cooling systems

GE imagination at work

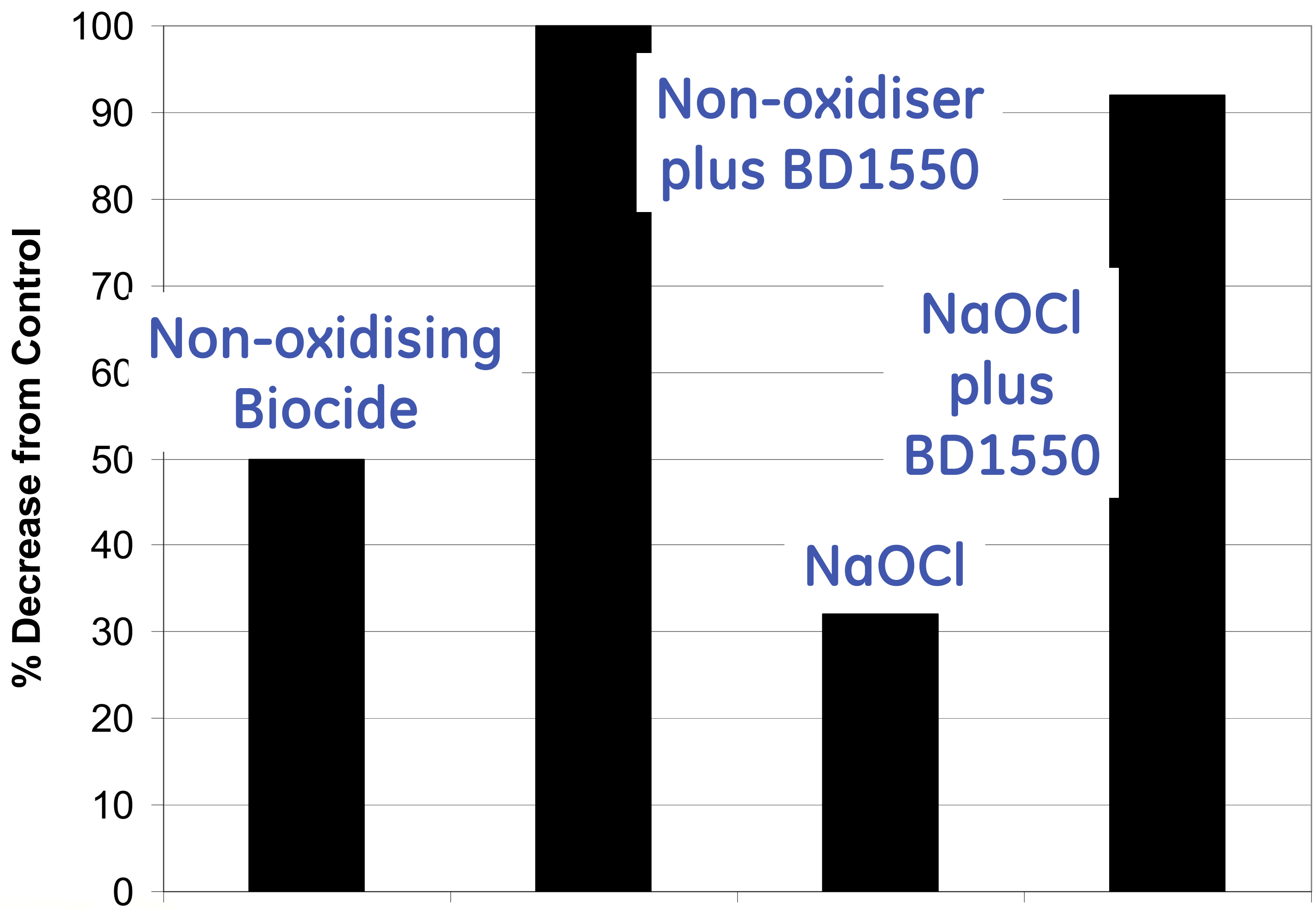
Spectrus BD1550

A true “BIODISPERSANT”

> Not just a biocide enhancer or surfactant for wetting biofilm to aid penetration of biocides

Spectrus BD1550 REMOVES a significant proportion of biofilm ON ITS OWN

Spectrus BD1550 with biocides Effectiveness on bulk water populations



Spectrus BD1550

Typically shot dosed (based on system volume) on its own or in conjunction with **intermittent or continuous** biocide dosing for biofilm removal

> **20 to 50 mg/l BD1550 shot dosed**
  - **if system is significantly fouled higher doses up to 100 mg/l may be required**

> **Frequency** of addition depends on several factors
  - **degree of biofouling**
  - **nutrient concentration**
  - **system half-life**
  - **supplemental biocide programme**

Legionella

What is Legionella

A group of bacteria found in aquatic environment.The most important member is Legionella Pneumophila .

Legionella

Legionellosis

Infections caused by Legionella in humans.

It is in two forms:

Legionnaires Disease

Pontiac Fever

Legionella

Infection Chain

Multiplication of the organism in water

Aerosol generation

Inhalation

Susceptibility of the individual

Legionella

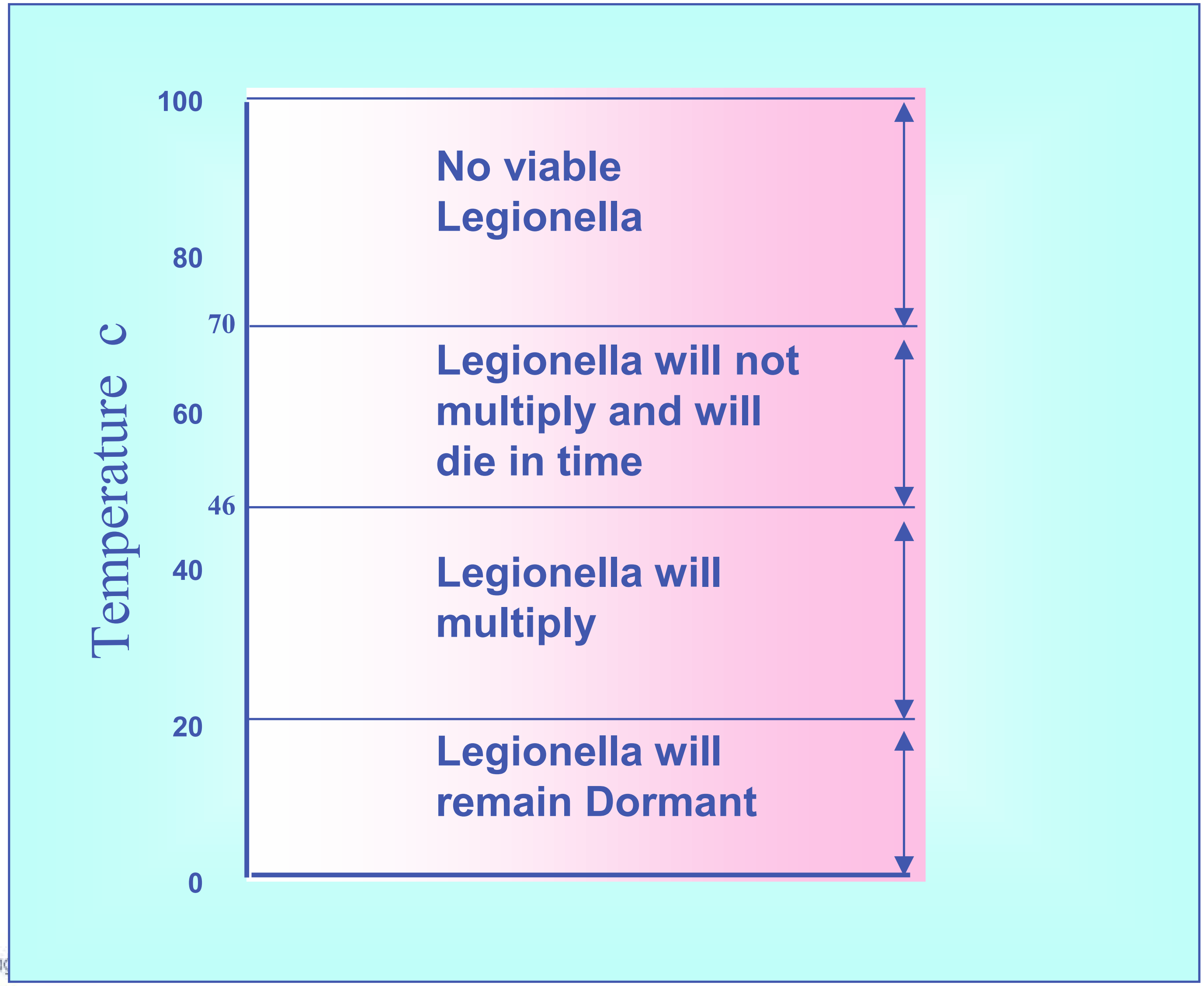
Potential Risk Systems.

Cooling towers/evaporative condensers

Hot water services (300 liters & over)

Spray humidifiers/air washers

Spa baths/pools



Temperature c
100
80
70
60
46
40
20
0
No viable Legionella
Legionella will not multiply and will die in time
Legionella will multiply
Legionella will remain Dormant

GE imag

Legionella Treatment

"Legionnaires' Disease is essentially man-made and is completely preventable."

Compliance procedure

- Identify source of risk
- Prepare a scheme for prevention/control
- Implement and manage precautions
- Keep records of the precautions implemented
- Appoint a person to be managerially responsible

Source: HSE HS(G)70

Monitoring Legionella

- Visual inspection of bulk and surface water.
- Check CT deck and fill for biofouling.
- Mist eliminator shall be inspected(if possible).
- Collect samples of suspected MB.
- Use dip slides for total aerobic count.

Treatment Control

Dispersants

Scale inhibition

Corrosion inhibition

Biocidal treatment

Treatment Control (cont)

Continuous halogen dosage.

- Free Residual halogen 0.5- 1.0 ppm over 24hrs.
- Halogen stabilizer is needed in alkaline program.
- Bio-dispersant / biocide program.
- Periodic use of non oxidizing biocides.
- Halogen compatible treatment program.

Treatment Control (intermittent)

- Free residual of 1.0 ppm at least one hour/day.
- Bio-dispersant / biocide program.
- Halogen compatible treatment program.

Routine on-line Disinfection

5 ppm free halogen residual for 6 hours for:

- Process leaks.
- Heavy bio-fouling.
- Uses reclaimed waste water.
- Stagnant water for long periods.
- Total aerobic bacteria 1000,000 cfu/ml.
- Legionella test result is 100.

Emergency Disinfection

If legionella is 1000 cfu/ ml.

- Shut of fans associated with cooling system.
- Shut of blow down.
- Close building air intake vents in the vicinity of CT.
- Start disinfection.

Summary (LG Control)

- Minimize water stagnation.
- Minimize process leaks .
- Maintain system cleanliness.
- Use complete and compatible water treatment program.
- Conduct routine inspections.

Chapter 6

MONITORING AND TROUBLESHOOTING

GE imagination at work

An effective treatment programme should :

Inhibit corrosion

Minimise deposition and fouling

Control Microbiological Activity

Be economical

Appropriate Treatment Levels are maintained through :

Cooling System Monitoring and Control

Poor Chemical Control

Overfeed

Underfeed

Highly variable results

Overfeed

High chemical costs

Poor treatment programme performance

Risk of environmental violations and fines

Underfeed

High corrosion rates

Increased equipment maintenance and replacement (i.e. replacing or cleaning of fouled or corroded heat exchanger tubes or bundles)

Reduced equipment performance (i.e. reduction in heat transfer)

Highly variable results

- No specific trend
- Unable to evaluate effectiveness of treatment programme
- Unable to identify changes which affect performance
- Difficult to troubleshoot

Typical Feed Control Methods

Manual

Semi-Automatic

Automatic

Manual

Periodic addition to tower sump

Manual addition to day tank

Chemical pump(s) manually operated (on / off)

Manual control of blowdown

Semi-Automatic

Chemical shot-fed by on/off timer control of pump(s)

Automatic

Microprocessor based Chemical Monitoring and Control System

Key features

Continuous monitoring of important parameters

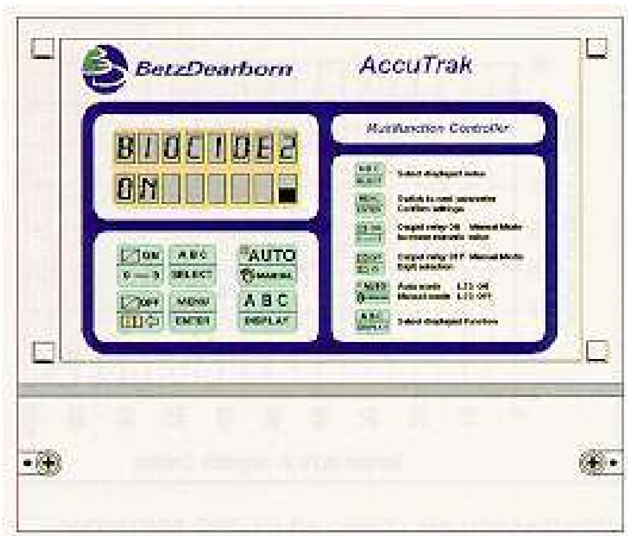
Continuous pH monitoring and control

Continuous control of blowdown

Precise chemical feed

Local indication and **remote alarm** capabilities for out of limit parameters

AccuTrak Controllers



Cooling & Boiler water controllers

Unique Biocide & Oxygen scavenger control strategies

Control up to **3** analogue inputs

11 different controllers in ONE

AccuTrak Controllers

Model 100
Blow down
Inhibitor
Biocides (2)

Model 200
pH control (2)

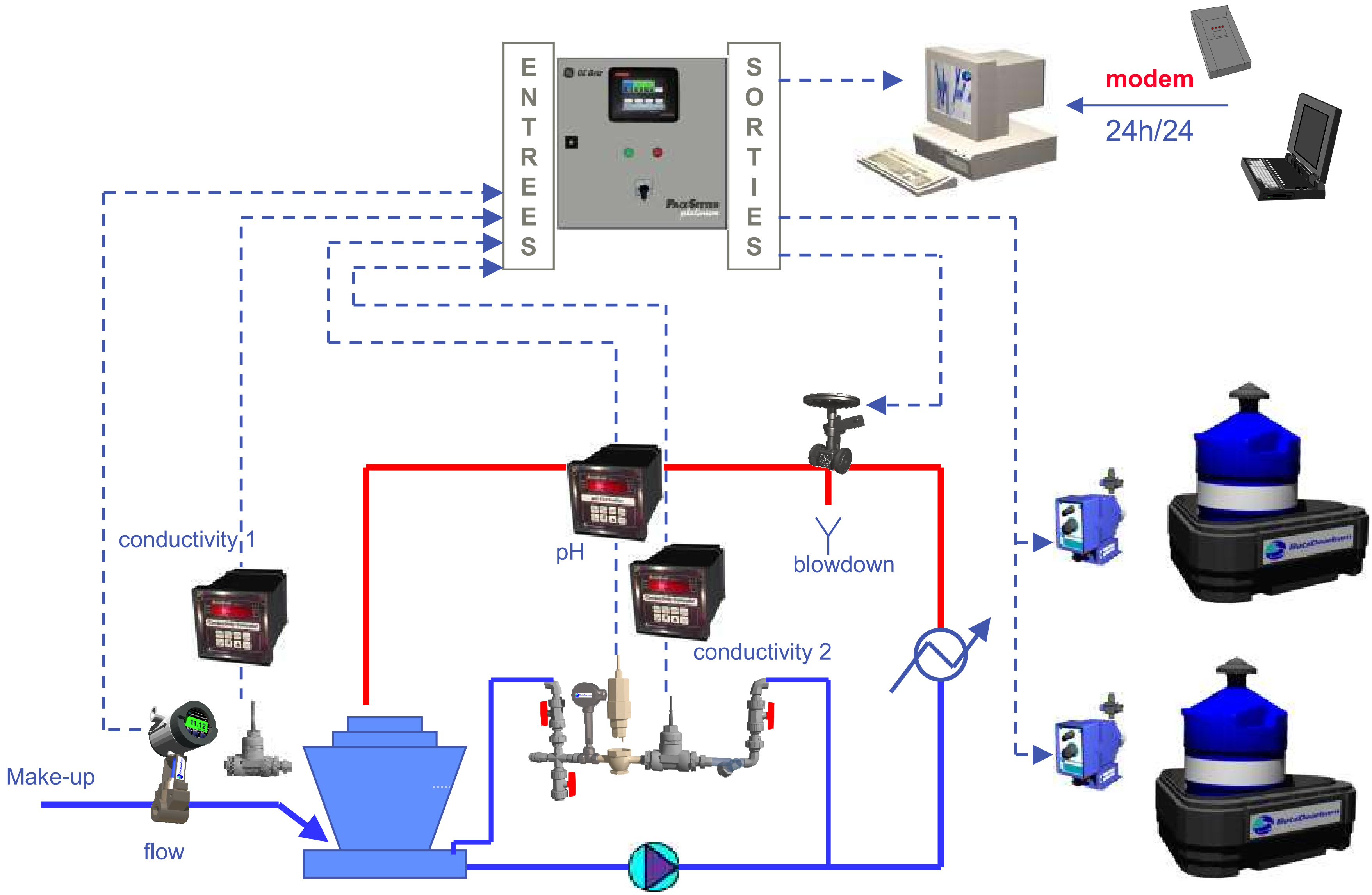
Model 600
(Boiler)
Blow down
O2 Scavenger
Inhibitor

Model 300
pH control
Blow down
Biocides (2)

Model 900
Blow down
Biocide
Free Chlorine

Control – Regulation of cooling water circuit.

Version with PLC/PC PaceSetter Platinum



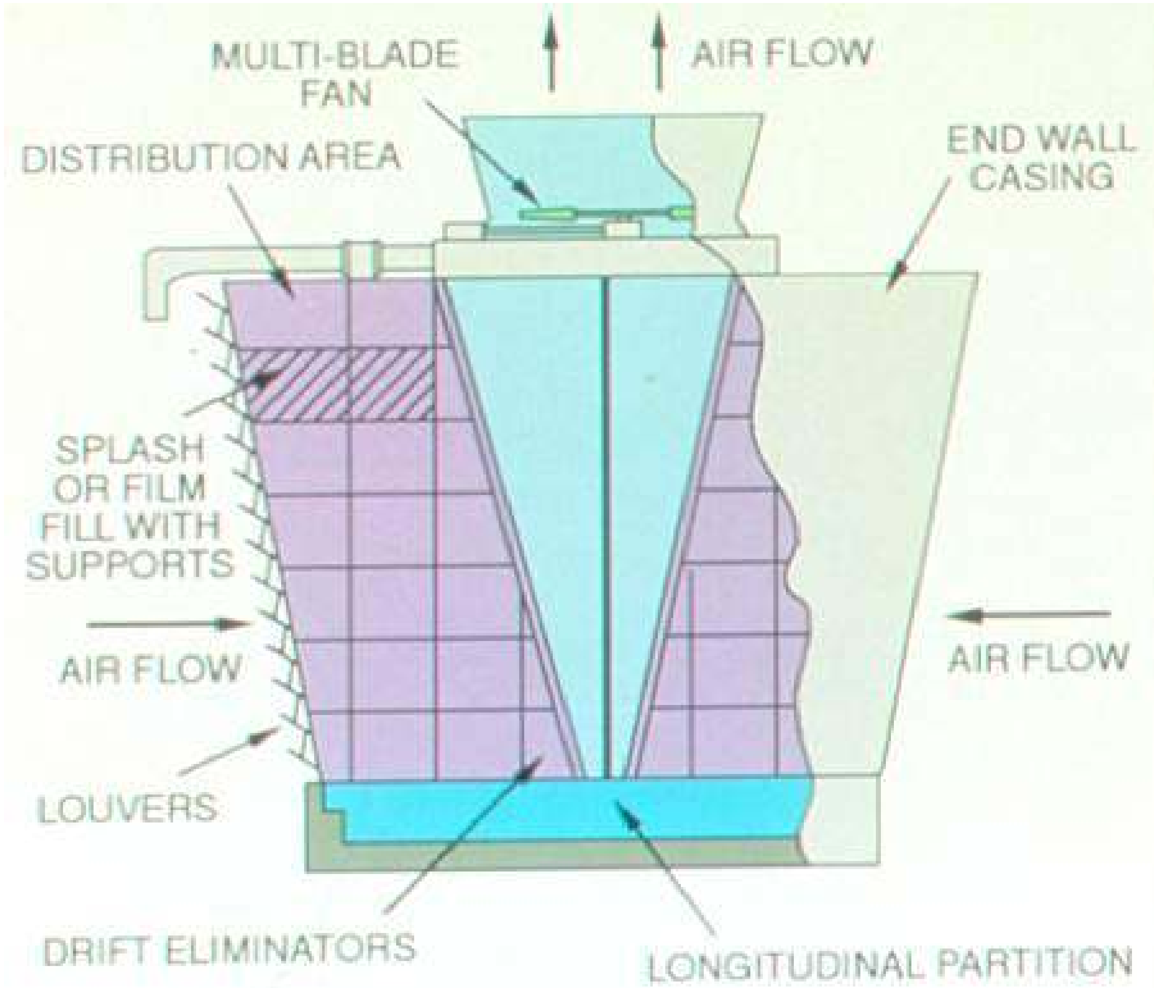
Benefit of Improved Control

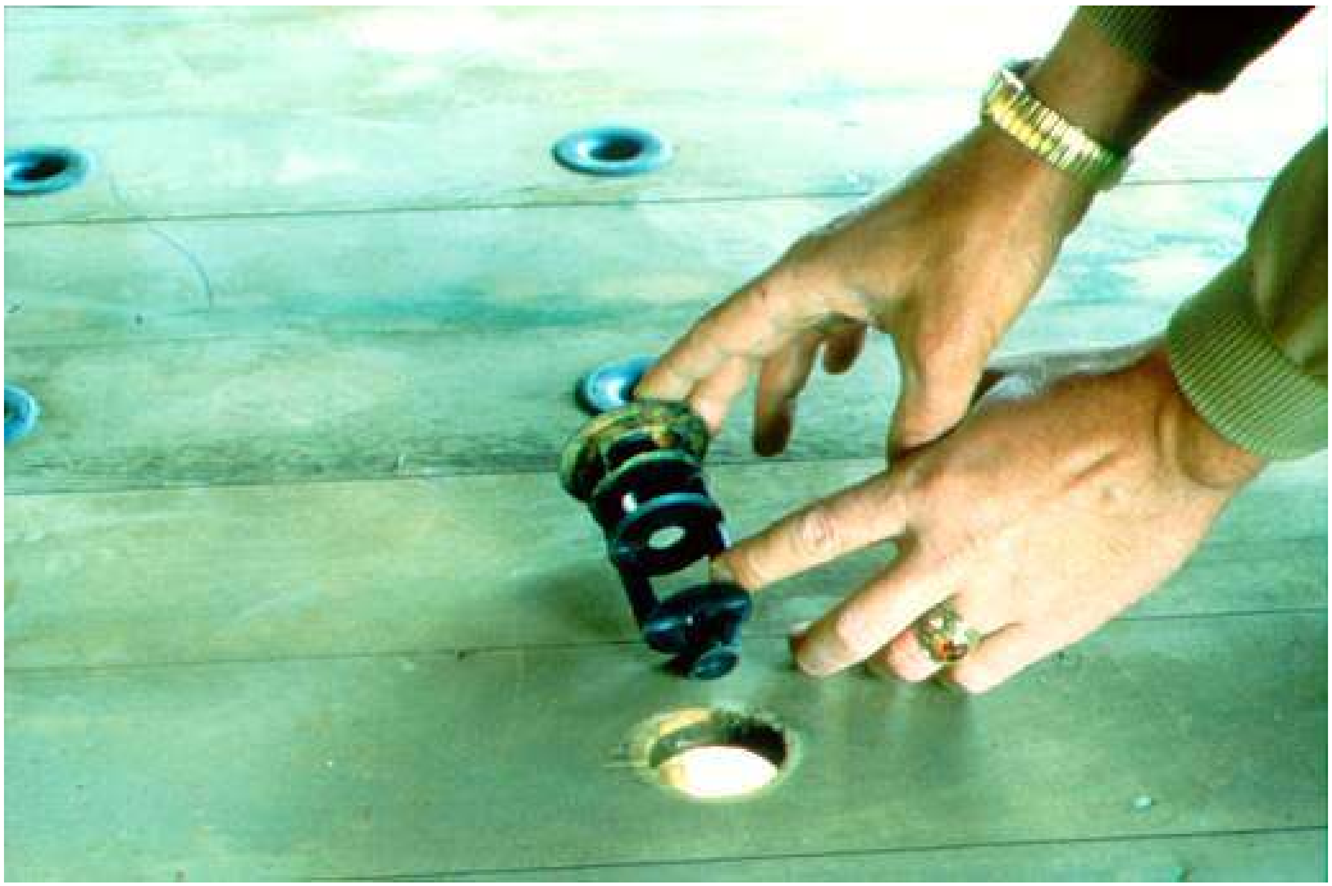
- **Reduced risks associated with chemical underfeed or overfeed**
- **Compliance with environmental regulations**
  Improved quality of plant operation
- **Increased water and energy savings**
  Improved plant productivity

Monitoring Tools

- **Inspection during operation is critical**

-Screens
- Mist eliminators
- Deck
- Fill
-Distributors
- Buildup on surfaces
- Air flow louvers
- Basin


MULTI-BLADE
FAN
AIR FLOW
DISTRIBUTION AREA
END WALL
CASING
SPLASH
OR FILM
FILL WITH
SUPPORTS
AIR FLOW
AIR FLOW
LOUVERS
DRIFT ELIMINATORS
LONGITUDINAL PARTITION



Field Testing

Water Analysis

Required to monitor and control treatment programme

Supply important information

Enable identification of low level contaminants

Parameters monitored (operating data)

Testing can include :

pH

Conductivity

Suspended solids

Alkalinity

Hardness

Phosphate

Other treatment components depending on programme

Microbiological populations

Deposit Analysis

Samples taken from :

Critical heat exchangers

Cooling tower

Areas of low water velocity and/or high heat flux

Frequency

Test Frequency will vary depending on :

Cooling System

Plant process

Plant personnel available

Compilation/Data Analysis

Manual

Weekly log sheets

Results can be graphed for data trending

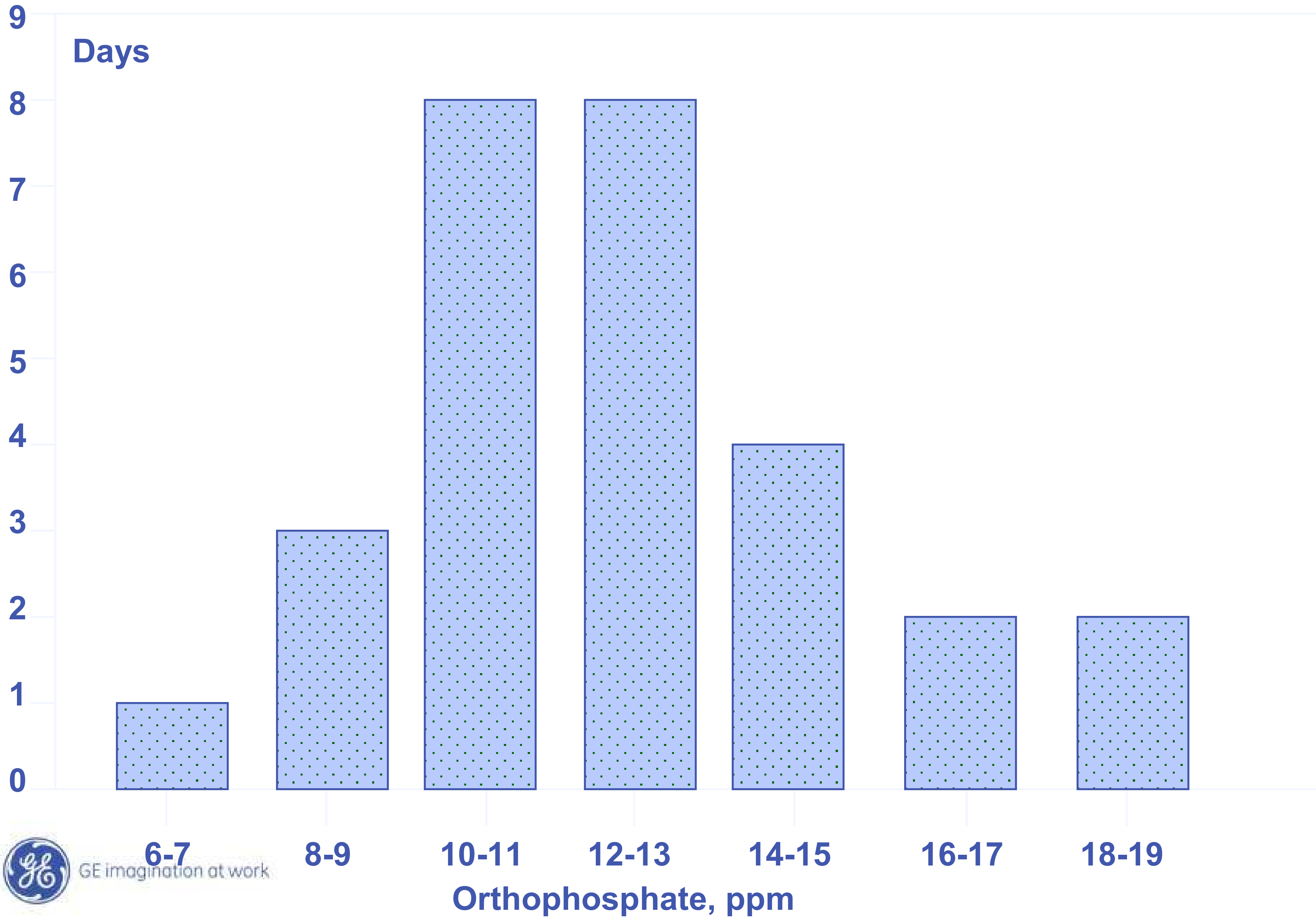
Weekly Log Sheets

Day	1	2	3	4	5	6	7
O-PO4 (ppm)	6	8	10	12	14	16	12
Day	8	9	10	11	12	13	14
O-PO4 (ppm)	10	10	8	10	12	18	14
Day	15	16	17	18	19	20	21
O-PO4 (ppm)	12	13	15	19	13	10	9
Day	22	23	24	25	26	27	28
O-PO4 (ppm)	11	10	13	16	15	13	10

Data Analysis

Reading (ppm)	6-7	8-9	10-11	12-13	14-15	16-17	18-19
Frequency (number)	1	3	8	8	4	2	2

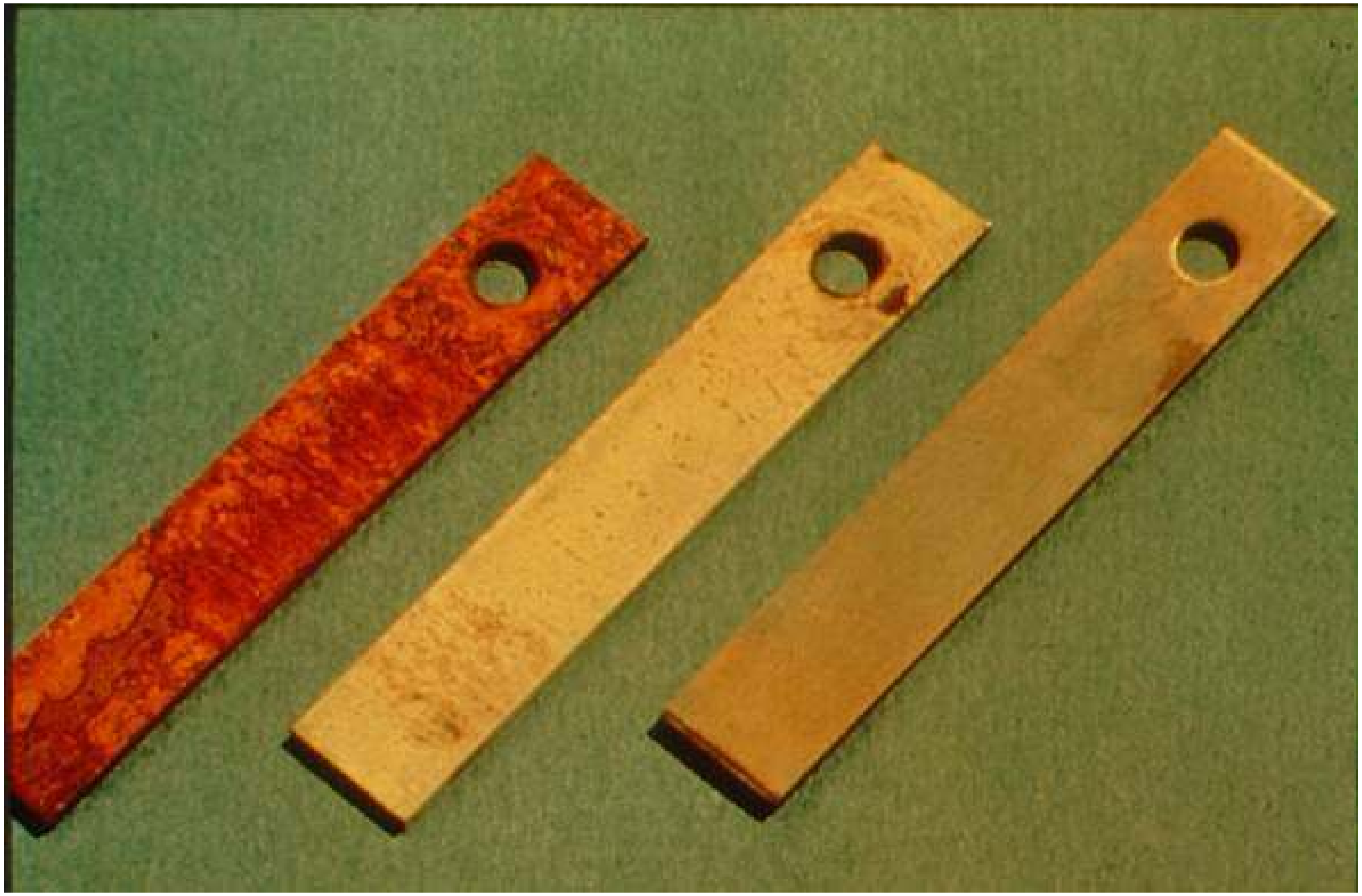
Graphing Results

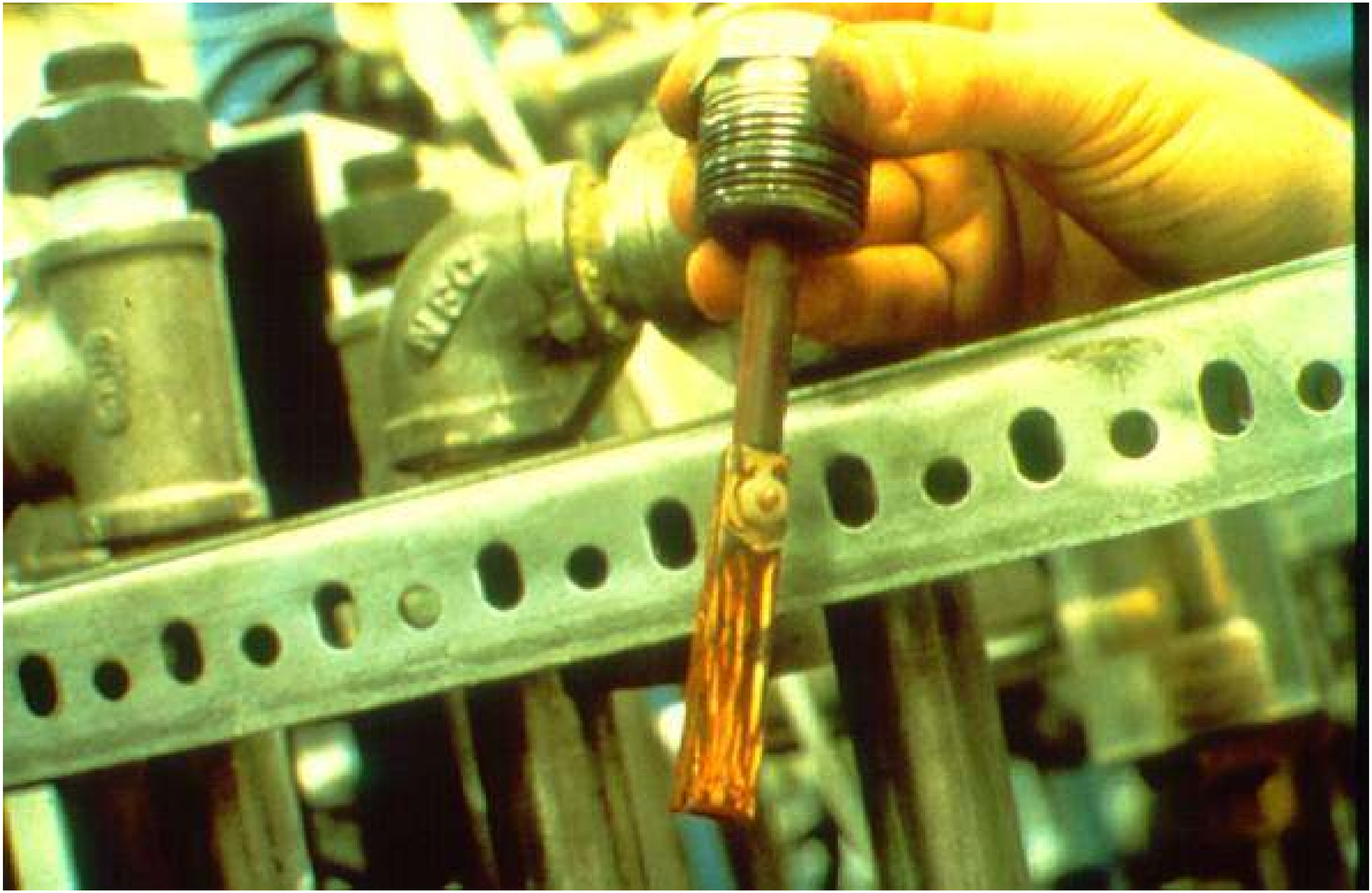


Corrosion Monitoring

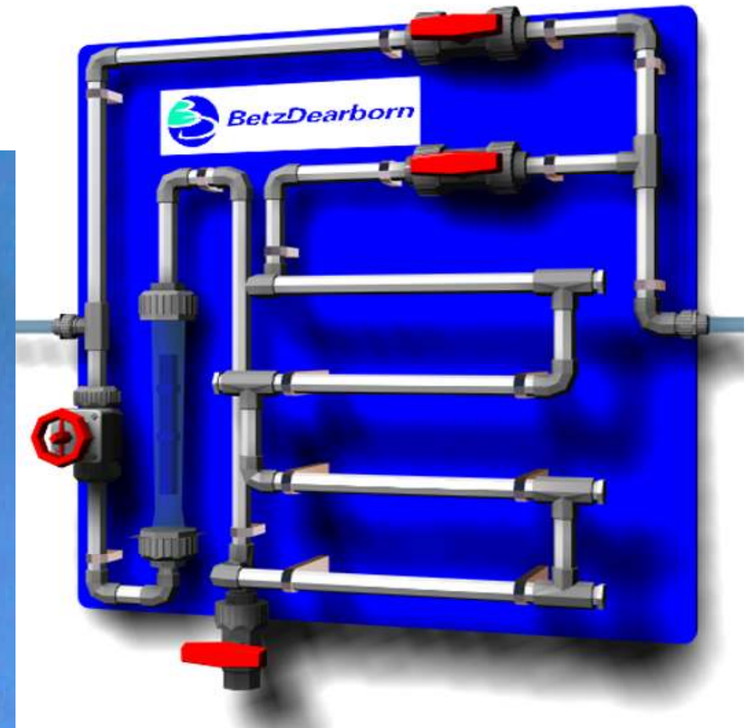
Coupons

Corrosion rate meter





CORROSION LOOP



Deposition Monitoring

Coupons

Monitall

Test heat exchanger


BETZ MonitAll™
A-C VOLTS
BETZ

MONITALL

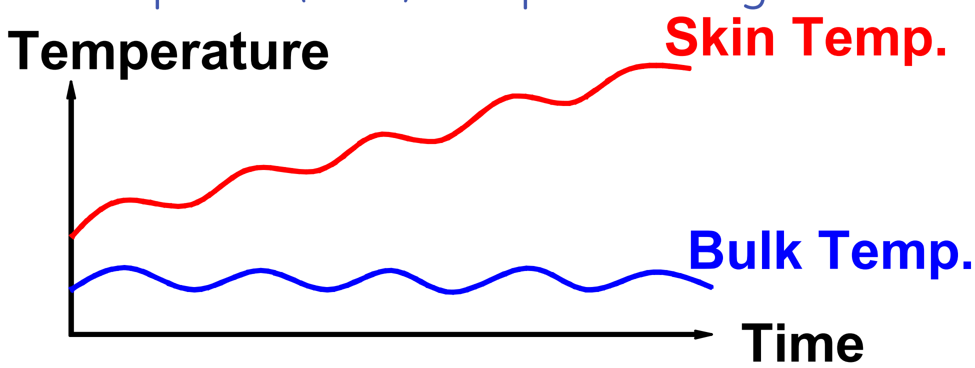
Fouling electric control

Heating probe equiped with thermocouple (skin probe temperature – bulk water temperature) – adjustable heat flux

Water circulates around the probe.

Monitor ΔT (skin temperature – bulk temperature)

Visual aspect of the probe (inox) – deposit analysis



Plot temperature/ ΔT graphs

Water flowrate: 50 to 150 l/h

Power 220V single phase 3A

Microbiological Monitoring

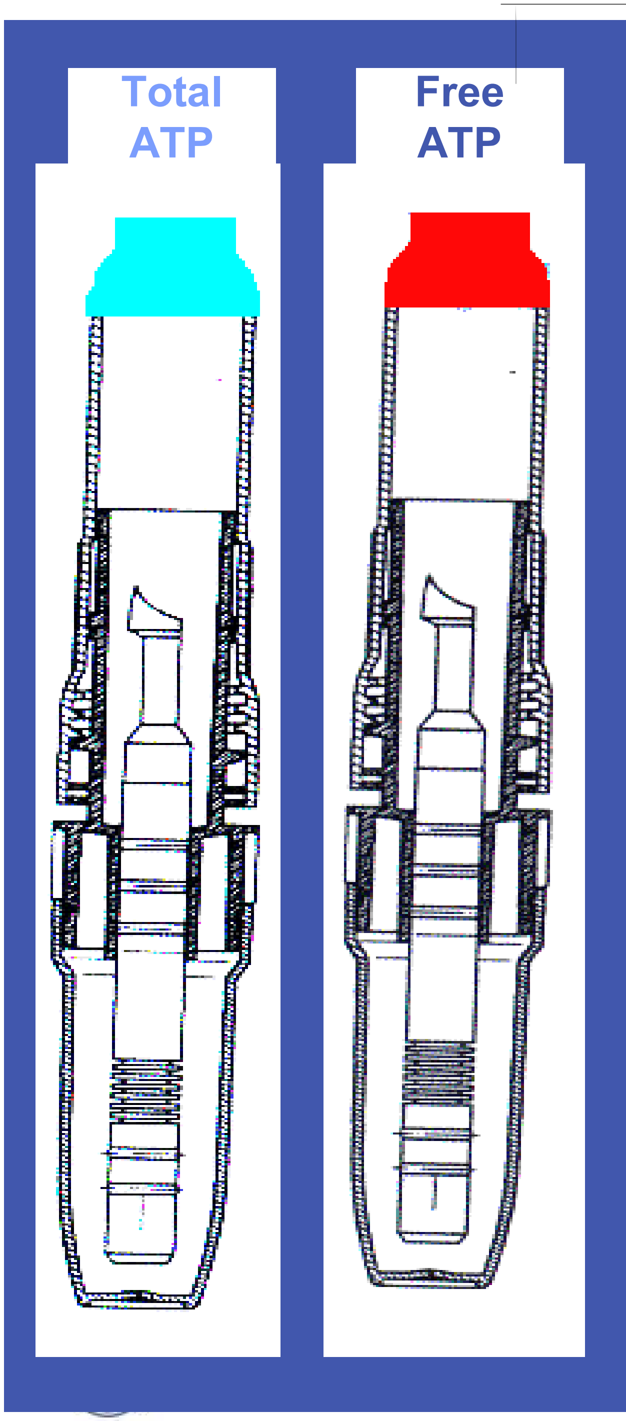
Micro-Organism counts

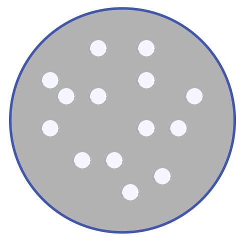
- > ATP
- > Dipslides
- > PetriFilm
- > Plate Counts

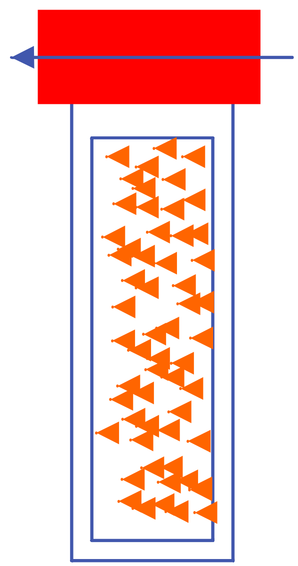
Biobox

Biofilm fouling monitor

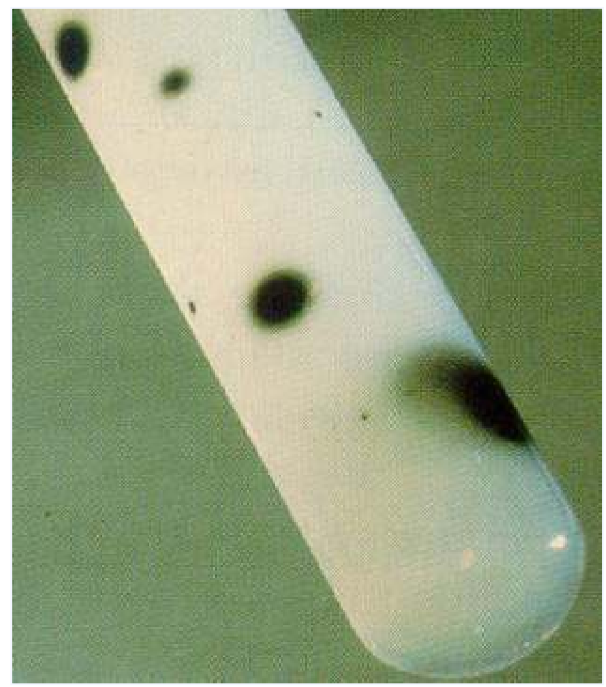
Stainless Steel coupons


Total ATP
Free ATP



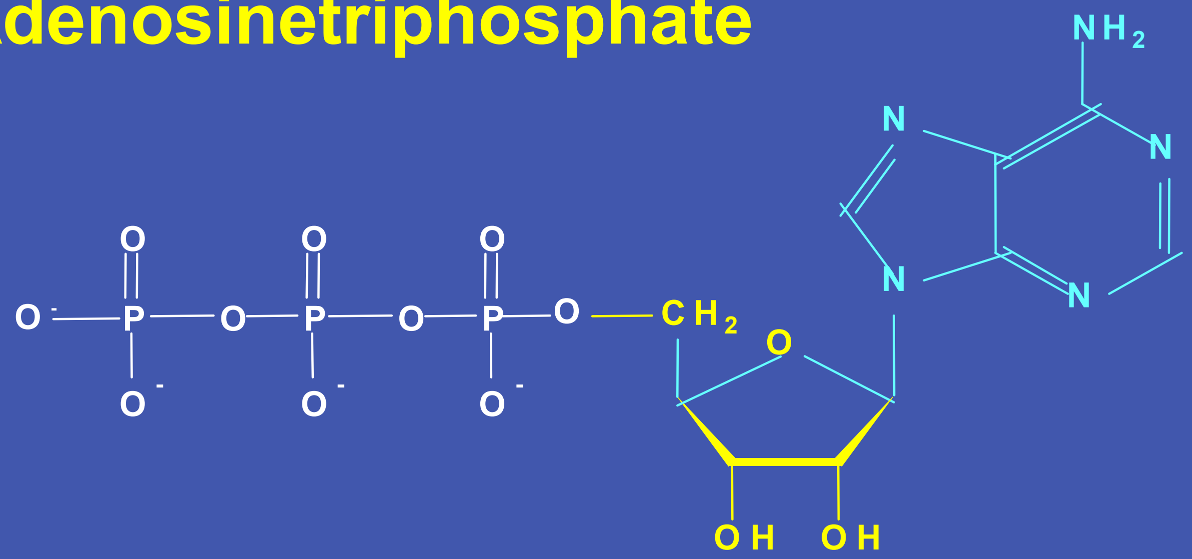



BIOSCAN
BetzDearborn



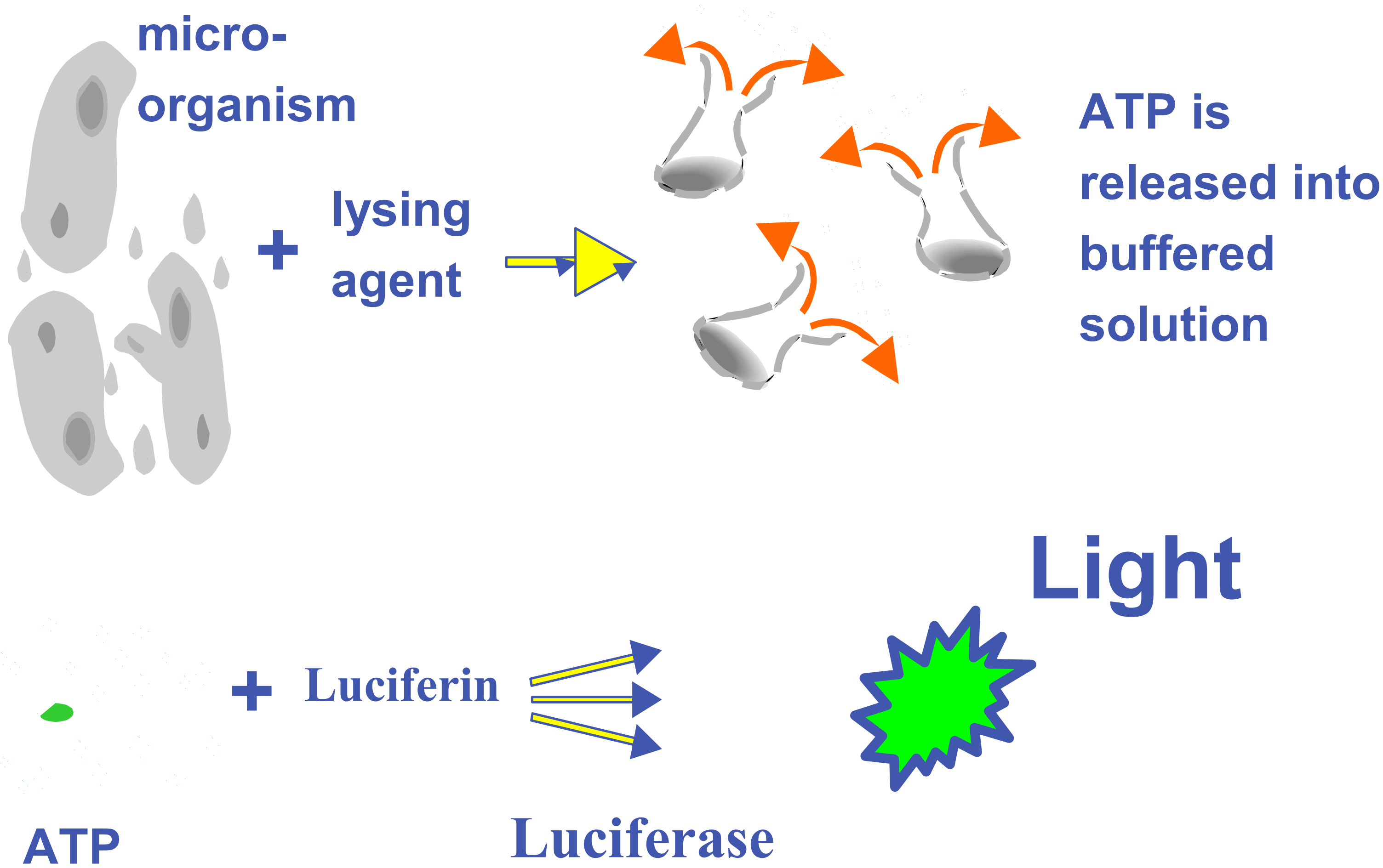
ATP

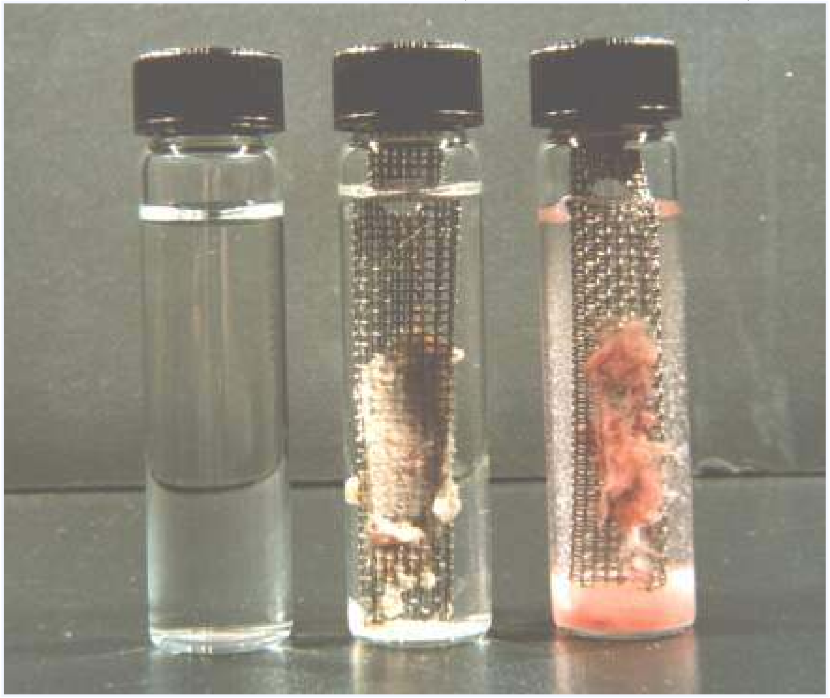
Adenosinetriphosphate

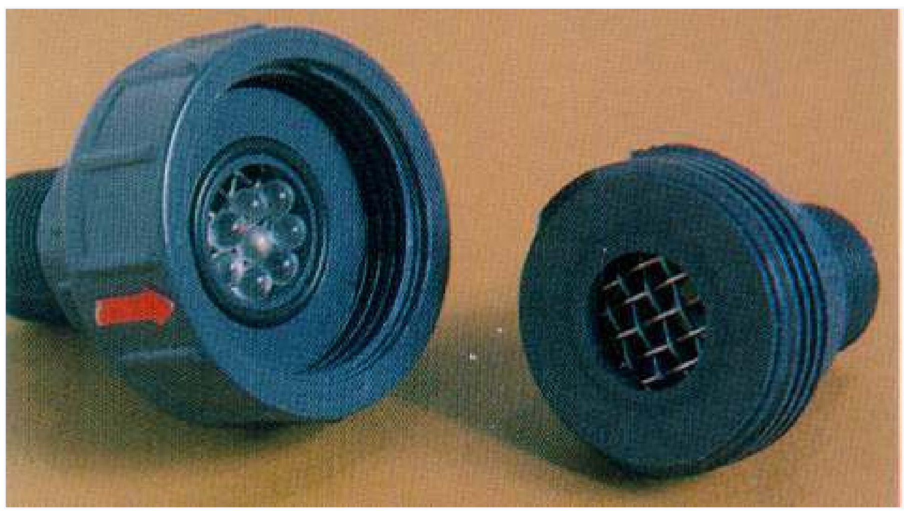


- Energy source for biochemical reactions
- Produced in ALL living cells
- Decreases if cell dies

ATP DETECTION







Field Analytical Equipment

Global and Advanced WAL test kits

> **GE Betz DR/2400 – GE Betz DR/890**

> **pH, Conductivity meter**

> **Digital titrator (Titrimetric analysis)**

Portable Field Microscope

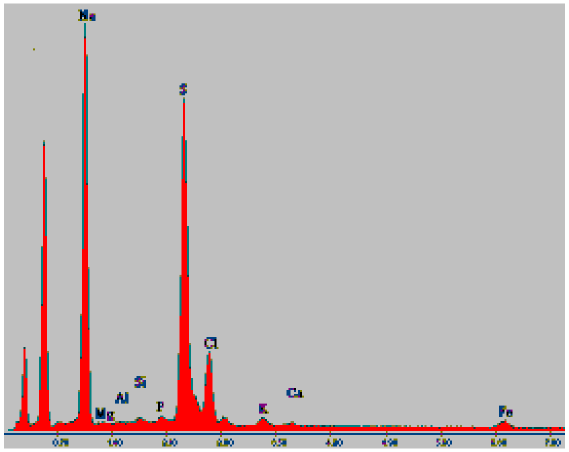
Microbiological Monitoring

> Cultivation methods : dipslides, petrifilm

> ATP method : **Bioscan II**

Laboratory - Analytical Services

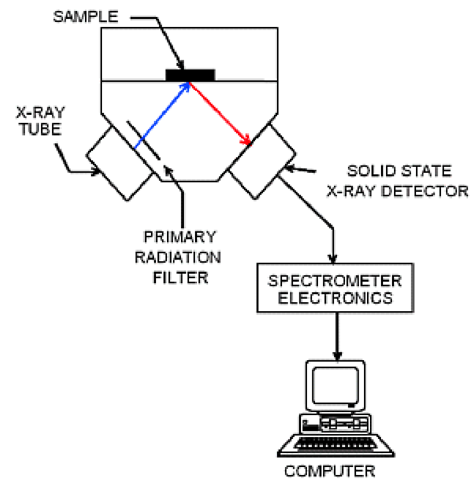
- Inorganic & Organic Analysis
- Microbiological Analysis
- Metallurgy



> *Characterization & Quantification*
> *ppb, ppm to % levels*
> *Bulk & localized surface analyses*
> *No certification of customer end product or conformance towards local regulations*

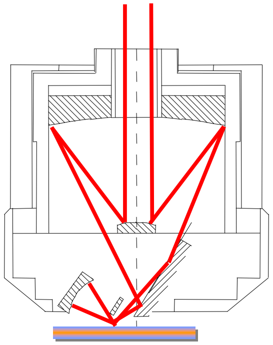
Inorganic Analysis

- > Inductive Coupled Plasma Emission Spectroscopy (Radial and Axial)
- > Flame - Atomic Absorption Spectroscop
- > Ion Chromatography
- > Segmented Flow-UV Analysis
- > Automated Titrimetric Analysis
- > Wavelength Dispersive X-ray Fluorescence Analysis
- > ECS 3000 – Coulometric Analysis



Organic Analysis

> Thermo Gravimetric Analyzer
> FT Infra-Red Spectroscopy
> CHNS-Analyzer
> Mass Spectrometry
> Gas & Liquid Chromatography
> Total Organic Carbon Analyzer
> Total Kjeldahl Nitrogen Analyzer



Metallurgy

1. **Surface Analysis**
   - Scanning Electron Microscope

2. **Failure Analysis**
   - Investigations & Recommendations

3. **Corrosion Coupons**
   - Corrosion Rate, Pit depth

TROUBLESHOOTING

Low PH Upset

Determine Causes

- Overfeeding Acid
- Sour Leak
- Process Contamination
- Chlorine overfeeding

Low PH Upset

Corrective Action

- Add Caustic or Soda Ash
- Increase Blow Down
- Track leakage or contamination source

High PH Upset

Determine Causes

- Investigate Caustic Addition
- Check for Process Contamination or Leakages

High PH Upset

- Increase Blow Down
- Add Acid to Adjust PH
- Adjust Treatment Feed Rates
- Increase Polymer Dose if Needed
- If unfiltered Po4 .vs. filtered >3
  - Add Polymer
  - Stop Phosphate Feed
- Recheck all Parameters

Unfiltered Iron

IF unfiltered Fe > 3

- Increase blow down
- Adjust polymer dosage
- Adjust treatment based on blow down

Corrosion

- Confirm Changes in Corrosion Data Trend.
  - Check Corrosion Meter
  - Inspect Corrosion Rack
- Check Changes in System Chemistry
- Investigate Contamination
- Review Program Guidelines
- Check chlorination Practice
- Check Microbiological Control

Corrosion Coupons

Installation Location

Return or Supply

Corrosion Coupons

Flow rate

Corrosion Coupons

Positioning the Coupon

Corrosion coupons

Different metallurgy Coupons

Corrosion Coupons

Testing Period

Fouling

- Check if velocity < 0.6 m/sec
- Check If Skin Temperature >65 C
- Investigate Microbiological Control

Fouling

- Adjust Polymer Dosage
- Increase Blow Down if Needed
- Adjust MB Control

Scale Formation

- Check for Water Chemistry Changes
- Check Contamination
- Review Water Treatment Program

Scale Formation

Calcium Carbonate

- Check LSI
  - < 2.5 for HEDP Program
  - < 2.8 for AEC Program
- Check Water chemistry Changes
- Investigate Exchanger Skin Temperatures Changes

Scale Formation

Phosphorous Salts

- Check over dosing
- Adjust Polymer Dosage
- Check Skin Temperatures
- Review Program Guidelines

Scale Formation

High Suspended Solids

- Adjust Polymer Dosage
- Back Flush the Exchanger
- Consider Installing Side Stream Filtration

Indication of Leaks

- Decrease in halogen residual
- Sudden increase in halogen demand
- Increase in MB count
- Biofilm formation over tower deck & surfaces
- Oil sheen on water
- Increase of turbidity
- H_2S smell
- Increase of corrosion rate
- Formation of black corrosion products

Process Leaks

Sweet Leak

- Increase Blow Down
- Increase Non Ionic Surfactant
- Increase Polymer Dosage
- Monitor Inhibitors Reserves

Process Leaks

Sour Leaks

- Increase Blow Down
- Increase Non Ionic Surfactant
- Increase Polymer Dosage
- Increase Inhibitors Reserves
- Stop or minimize Chlorine Feed
- Increase Non Oxidizing Biocide

Mechanical Response

- IF possible isolate exchanger
- Increase blow down
- If possible direct BD from exchanger effluent.
- Skim hydrocarbon overflow basin & deck
- Increase backwash frequency of side stream filter
- Run all circulation pumps to maximize velocity

MB Fouling

- Review MB Control Program
- Increase dose of bio Surfactant
- Check Sessile Activity With Bioscan
- Back Flush or Air Pump Fouled Exchanger Till temperature Drops
- Investigate Contamination