COOLING TOWER SEMINAR

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AGENDA

1. Types Of Cooling Systems.
2. Types Of Cooling Towers
3. Cooling Towers Definitions & Calculation.
4. Basic Cooling Water Treatment principles.
5. Microbiological Contamination.
6. Veolia Water Approach To Control Legionella.

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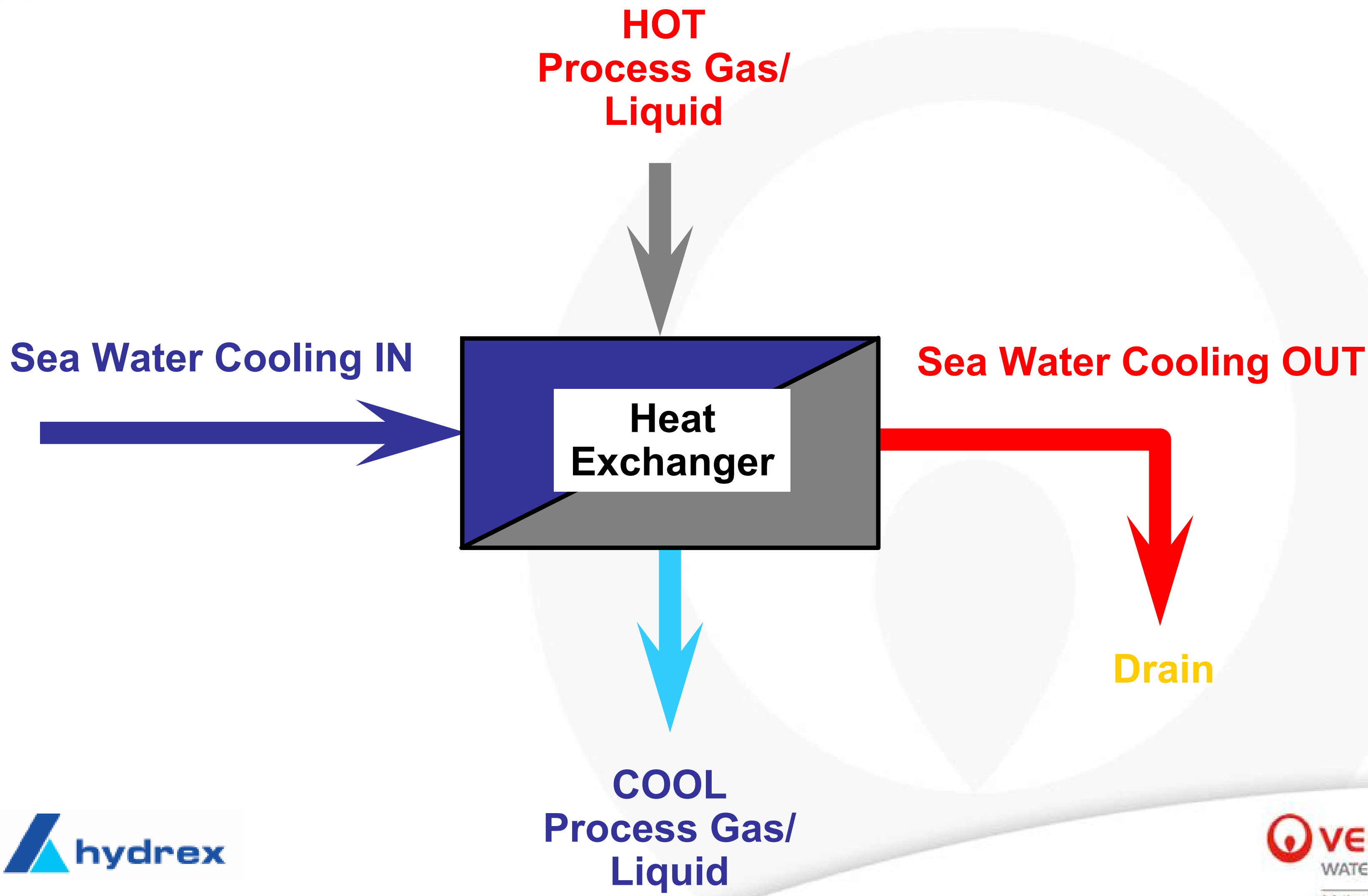
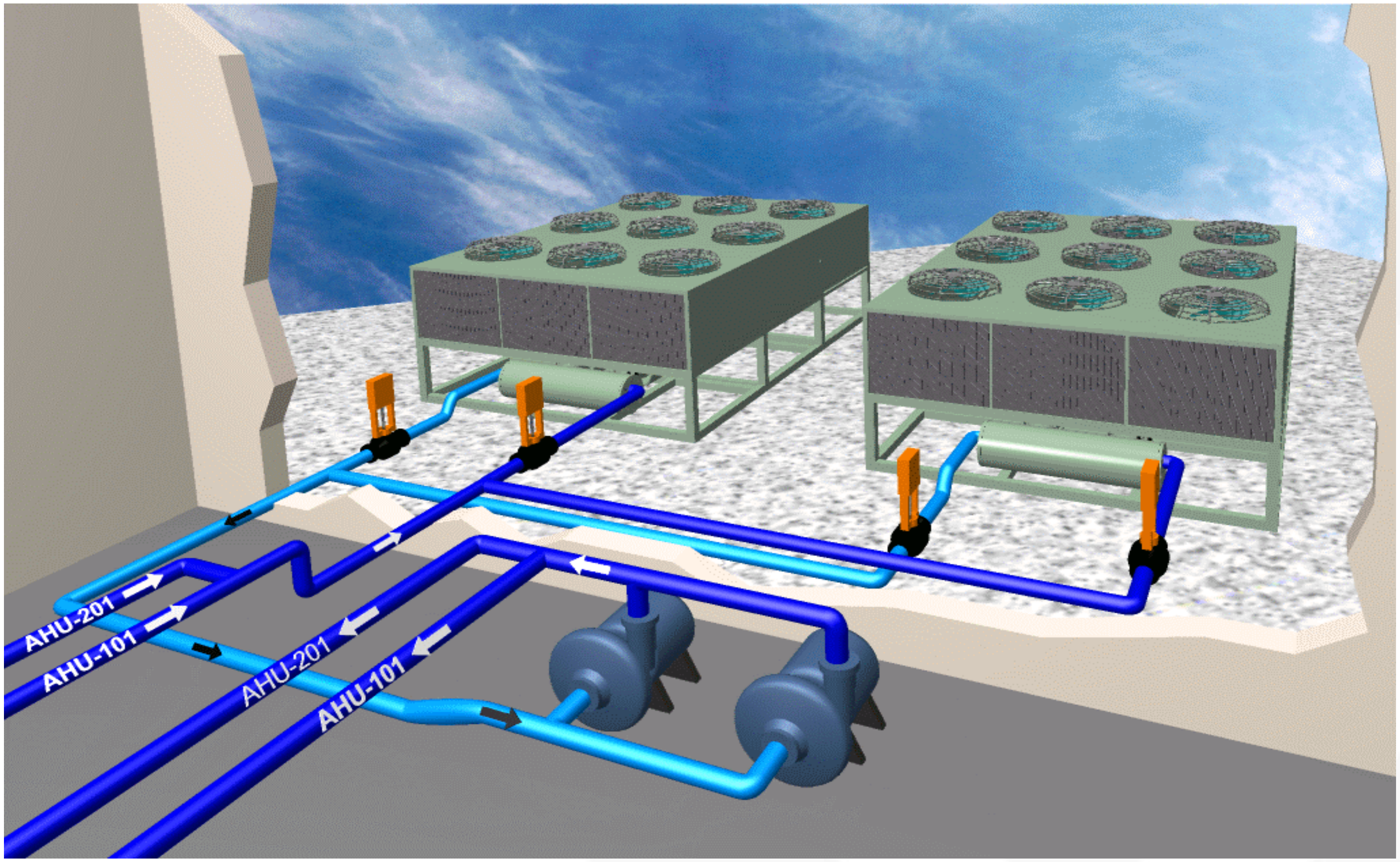
1. TYPES OF COOLING SYSTEM

- **3 kinds of cooling systems..**
  - ✓ **Once-Through.**
  - ✓ **Closed Loop.**
  - ✓ **Cooling Towers (Open Circuit).**

ONCE – THROUGH – BLOCK DIAGRAM

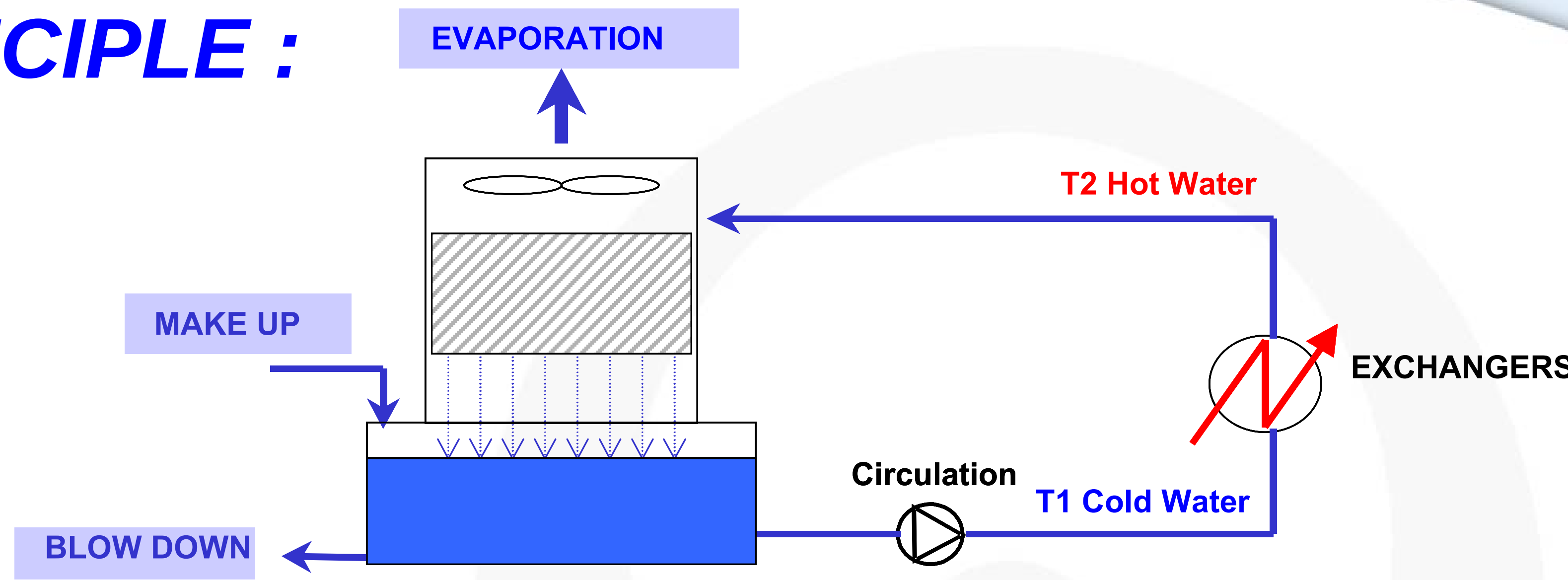


CLOSED LOOP



COOLING TOWERS (OPEN CIRCUIT)

>PRINCIPLE :



- Water cooled after having cooled the process on an atmospheric cooling agent.
- Air is the cooling agent.

Definition of a Cooling Tower

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

2. TYPES OF COOLING TOWERS

Cooling Principle

- **Water Evaporation, Enhanced With High Contact Surface : THE FILL**
- **Air flow generation methods :**

1. **Natural Draft.(Flowrate Depends on Atmospheric Condition)**
2. **Mechanical Draft. (Constant Flowrate)**

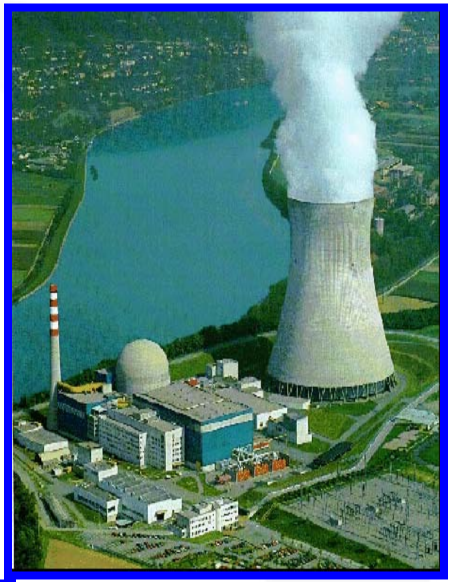
Rule of Thumb...

1 BTU will raise the temperature of 1 pound of water 1 degree Fahrenheit.

TYPES OF COOLING TOWERS

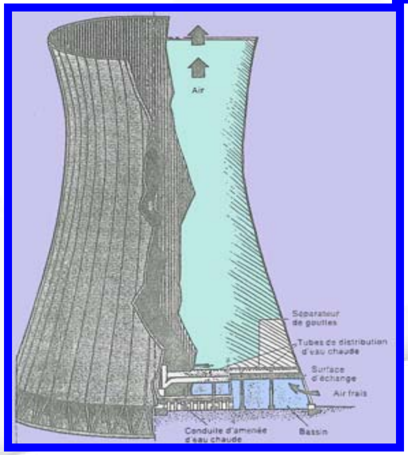
1. NATURAL DRAFT :

- Tall chimney with hyperbolic shape.
- Warm, moist air naturally rises due to the density differential to the dry, cooler outside air. This produces a current of air through the tower.



Applications :

- Refinaries.
- Power Plants.
- Petrochemicals.



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TYPES OF COOLING TOWERS

2. MECHANICAL DRAFT COOLING TOWERS

which uses power driven fan motors to force or draw air through the tower.

Three types……

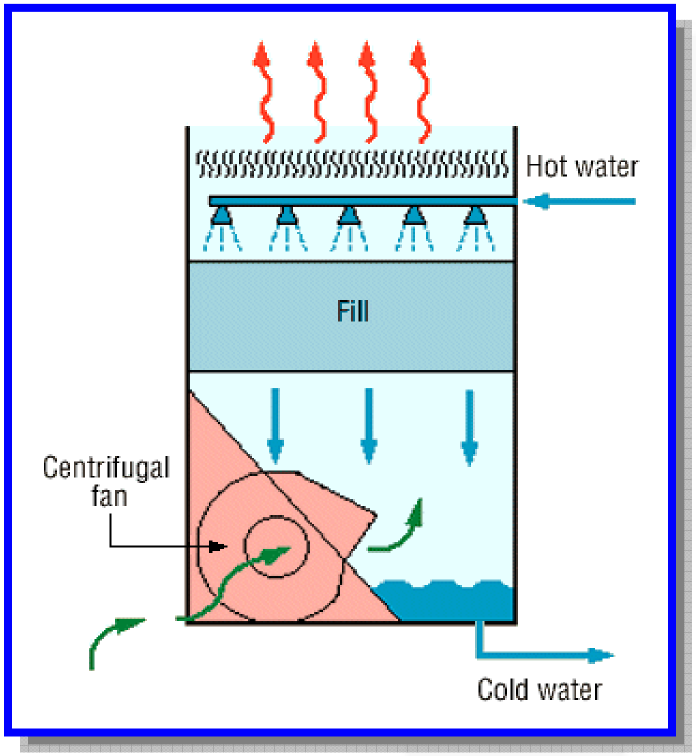
A. Forced draft.

B. Induced draft cross flow.

C. Induced draft counter flow.

TYPES OF MECHANICAL DRAFT COOLING TOWERS

A. Forced Draft Cooling Towers …



- Water distributed via spray nozzles
- Air blown through tower by centrifugal fan at air inlet.

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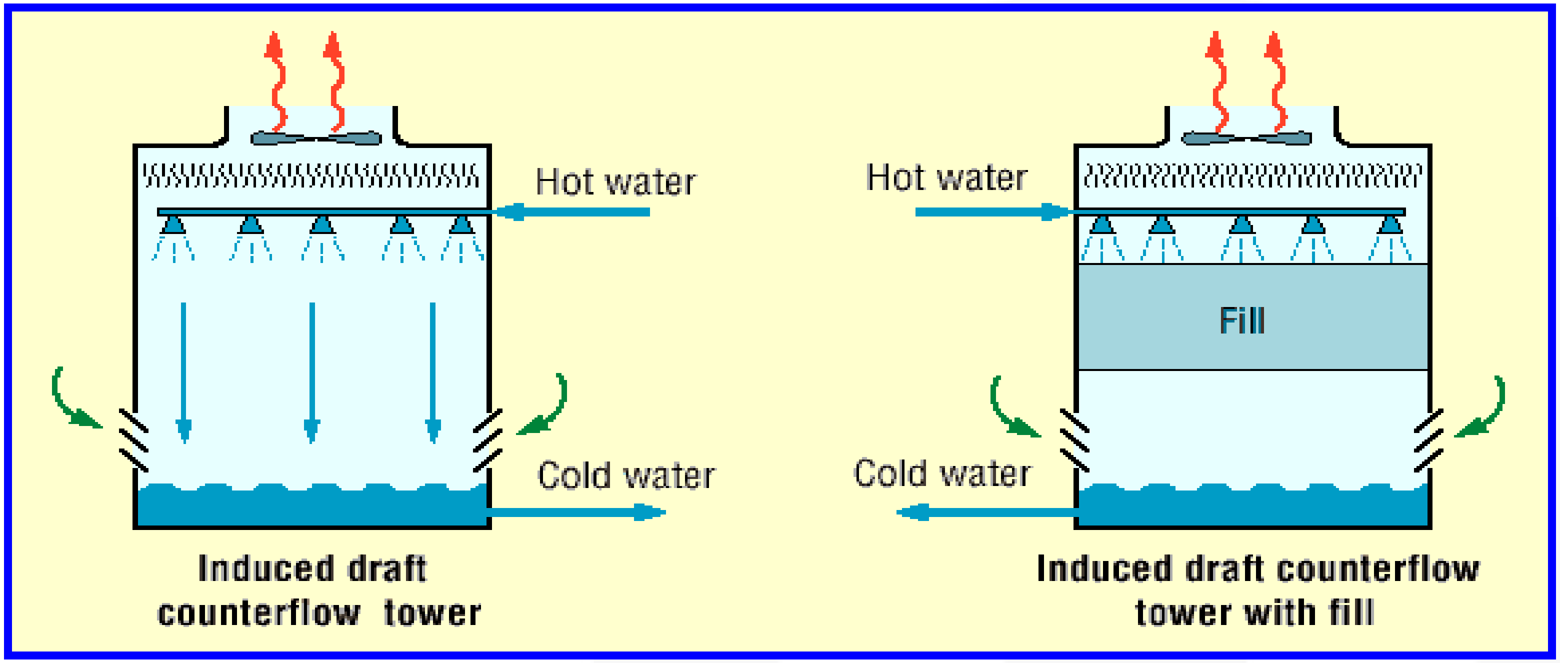
TYPES OF MECHANICAL DRAFT COOLING TOWERS

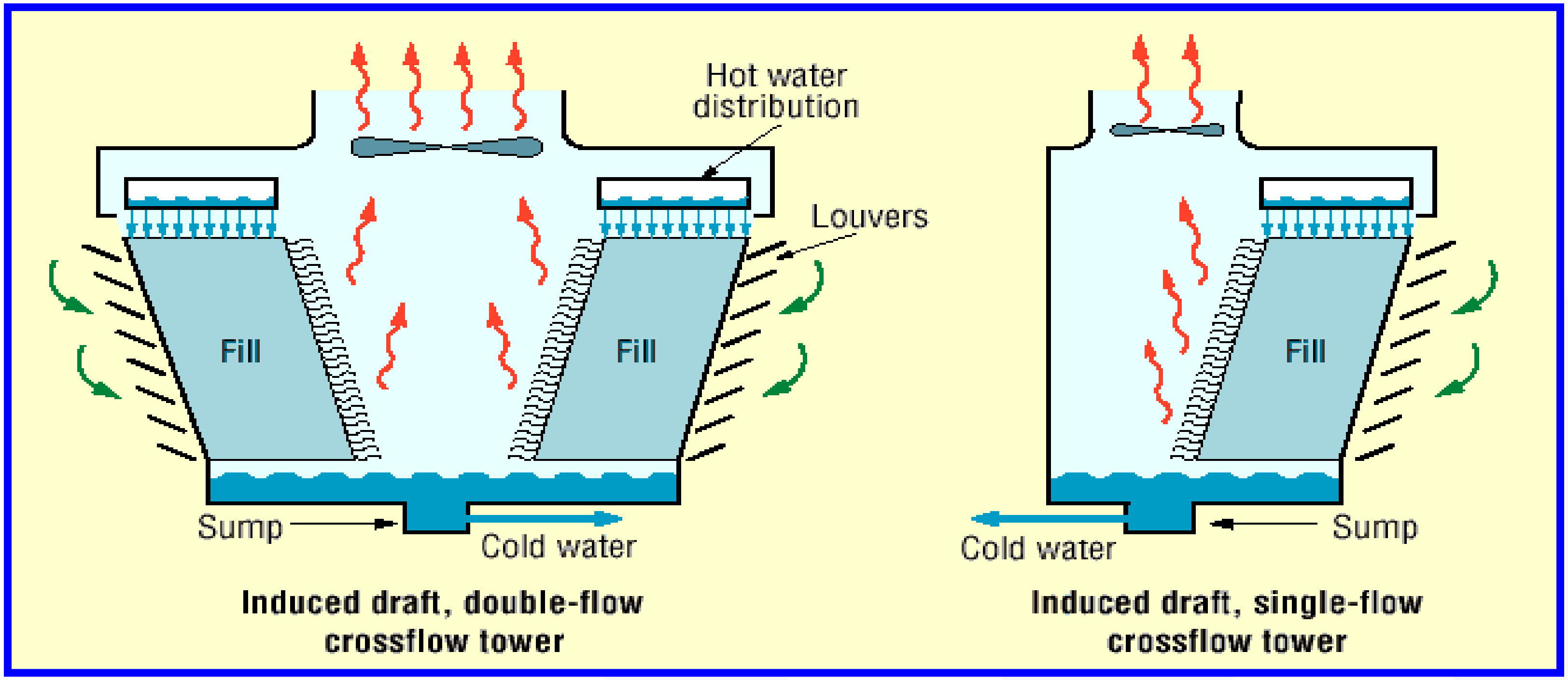
B. Induced Draft Counter Flow CT……



- Hot water enters at the top.
- Air enters at bottom and exits at top.
- Uses forced and induced draft fans.

TYPES OF MECHANICAL DRAFT COOLING TOWERS

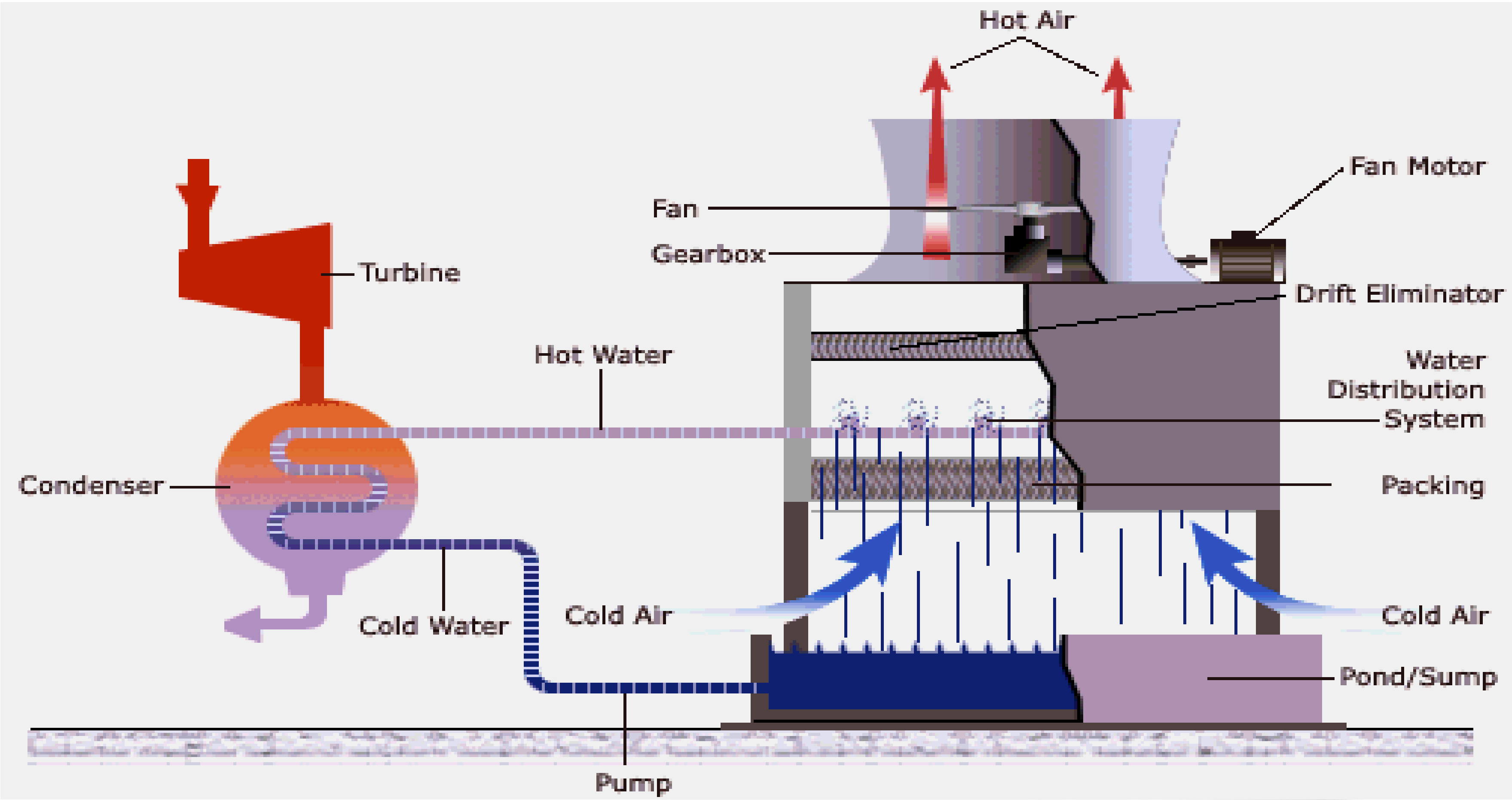
C. Induced Draft Cross Flow CT



- Water enters top and passes over fill
- Air enters on one side or opposite sides
- Induced draft fan draws air across fill

TYPES OF MECHANICAL DRAFT COOLING TOWERS

Water Flow Diagram - Induced Draft Cross Flow C.Towers



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3. COOLING TOWERS

DEFINITIONS & CALCULATIONS

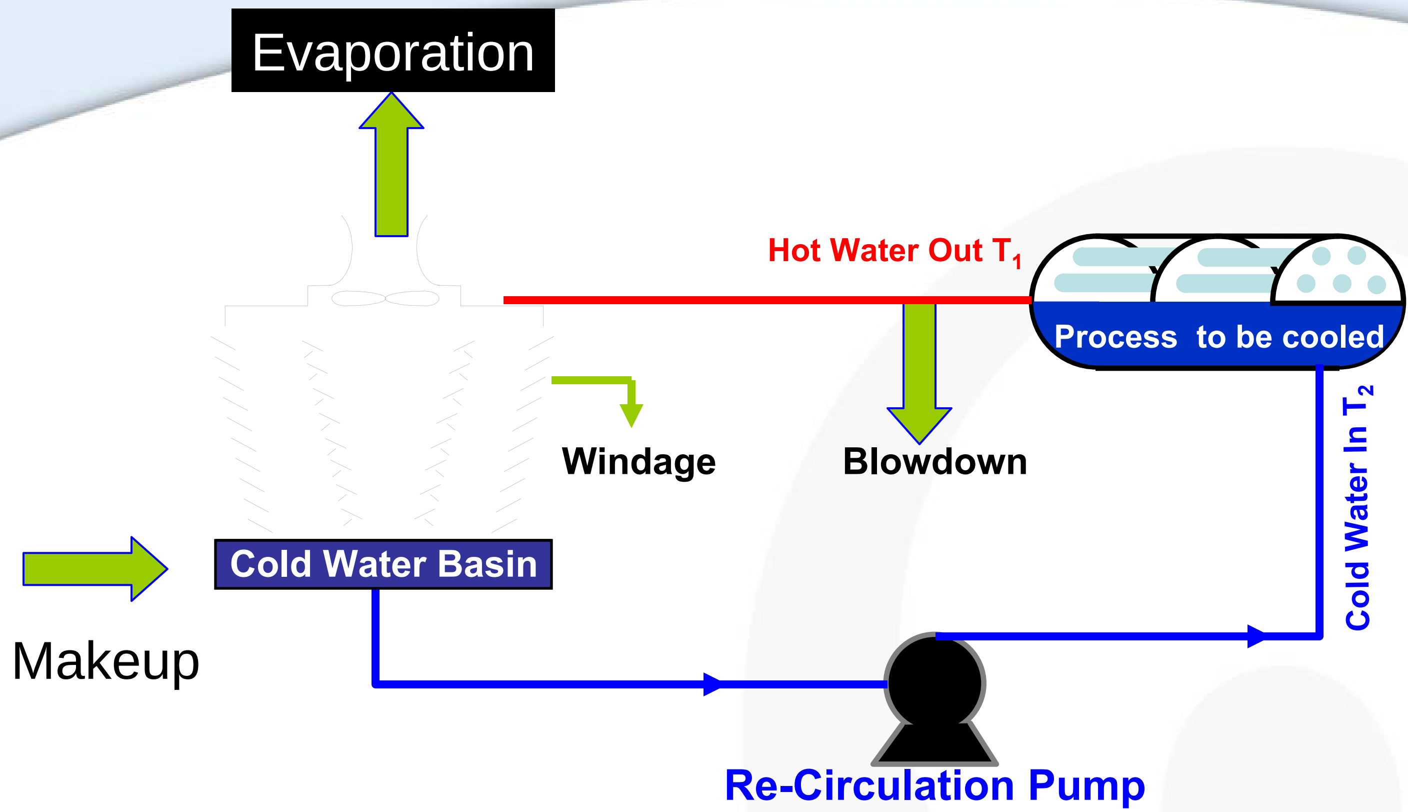
Cooling Water Mass Balance

- 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 RATE

MAKE UP WATER



Makeup = Evaporation + Blow-down + Windage

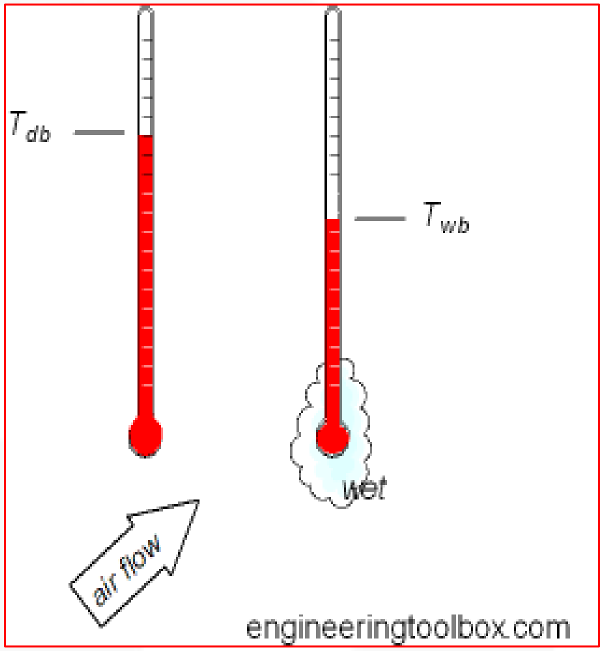
RECIRCULATION RATE (R.R)

It is the Flow of cooling water being pumped through the entire plant cooling loop.

Temperature Differential (ΔT)

❑ 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.

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Temperature Differential (ΔT)

- **As wet bulb temperature changes , Performance of cooling tower changes.**

Wet bulb Temperature		% Capacity Available
85 ^{0}F		10
80 ^{0}F		82
79 ^{0}F		91
78 ^{0}F	Standard Rating	100
77 ^{0}F		107
76 ^{0}F		112
75 ^{0}F		120
74 ^{0}F		126
73 ^{0}F		131
72 ^{0}F		138
71 ^{0}F		142
70 ^{0}F		148
65 ^{0}F		170
60 ^{0}F		182

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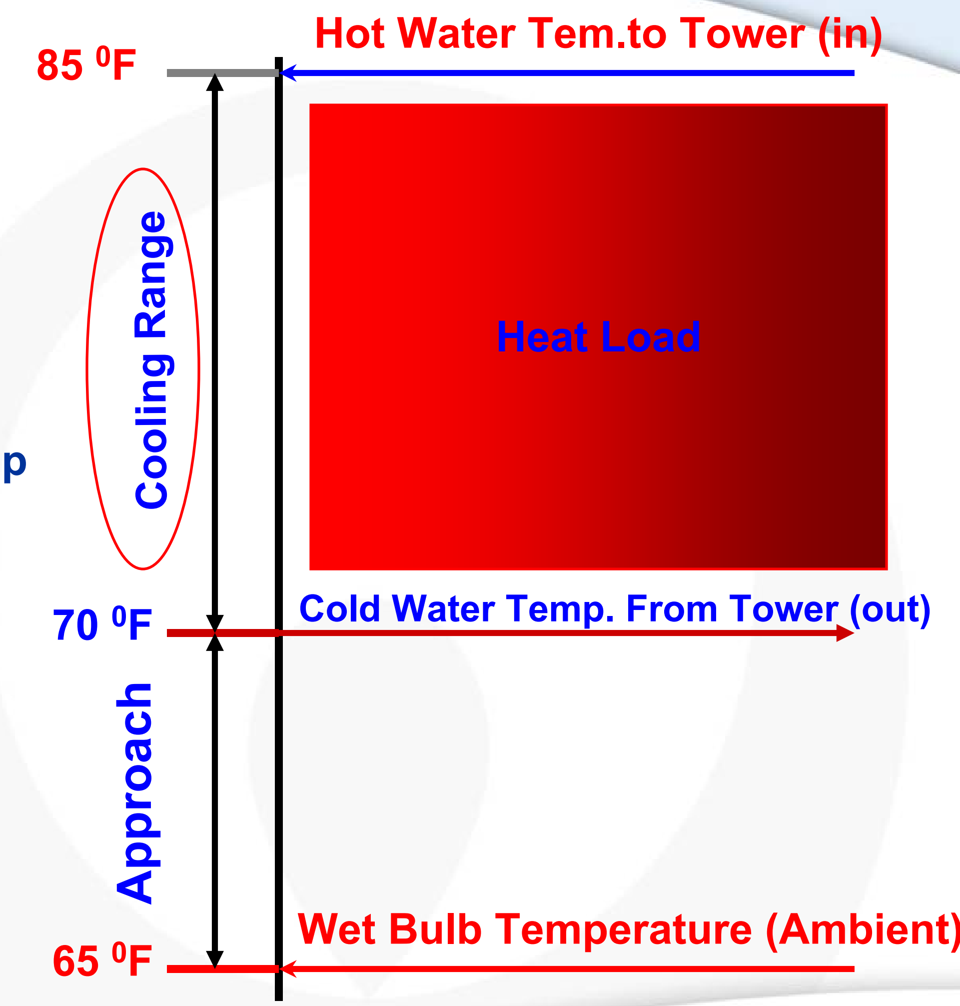
Temperature Differential (ΔT)

Cooling Range :

Difference between cooling water inlet and outlet temperature:

Range (°C) = CW inlet temp – CW outlet temp

High range = good performance



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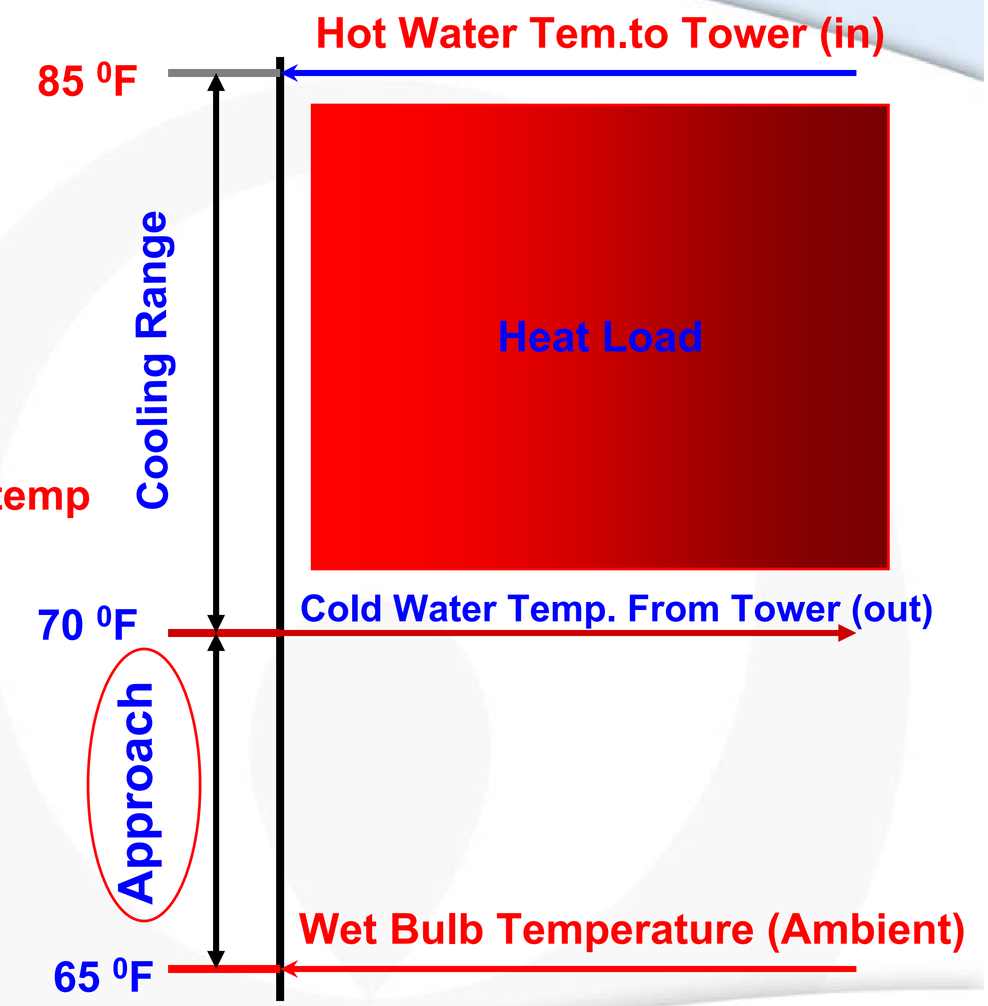
Temperature Differential (ΔT)

Approach :

Difference between cooling tower outlet cold water temperature and ambient wet bulb temperature:

Approach (°C) = CW outlet temp – Wet bulb temp



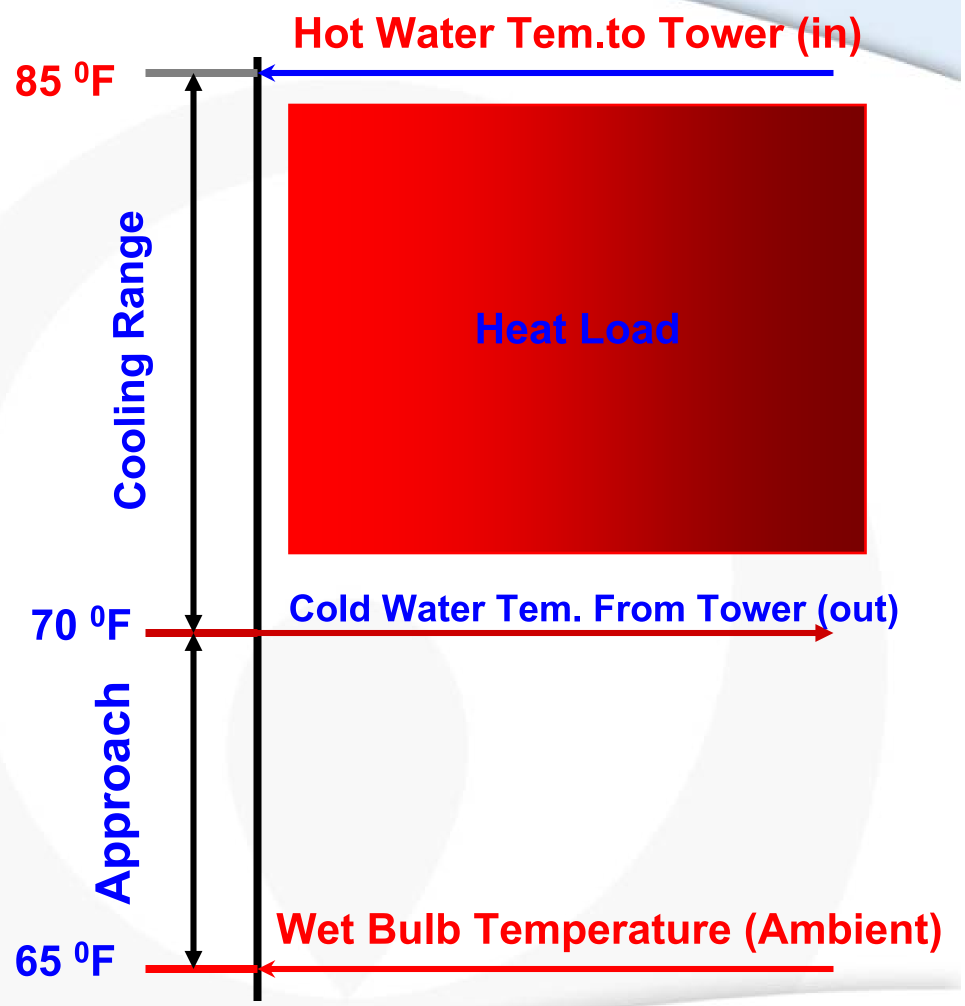
Temperature Differential (ΔT)

Effectiveness :

Effectiveness %

= 100 x (Range / (Range+Approach))

High effectiveness = Good Performance



EVAPORATION RATE (LOSS) – E.R

Definition :

Water quantity (GPM) evaporated (Loss) to atmosphere for cooling duty.

As a rule of thumb …….

For each 10ºF(5.6^{0}C) that the re-circulated water needs to be cooled, 1% of the cooling water is evaporated in the cooling tower.

$$\text{Evaporation Rate (GPM)} = \text{R.R X } (\Delta T/1000)$$

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BLOW-DOWN RATE – B.R

Definition :

The portion of the concentrated cooling tower water intentionally discharged from the cooling tower to maintain an acceptable water quality in the cooling tower.

$$\text{Blow-Down Rate (GPM)} = \frac{\text{Evaporation Rate}}{\text{Cycle of Concentration} - 1}$$

CYCLE OF CONCENTRATON – C.C

Definition :

The number of times the T.D.S content of the cooling water is increased in multiples of itself.

The cycles of concentration can be estimated by measuring the T.D.S or conductivity or some specific ion in both the recirculating water (CW) and the makeup water (MU) and dividing the makeup number into the tower water number.

$$\text{Cycles Of Concentration} = TDS_{CW} / TDS_{MU}$$

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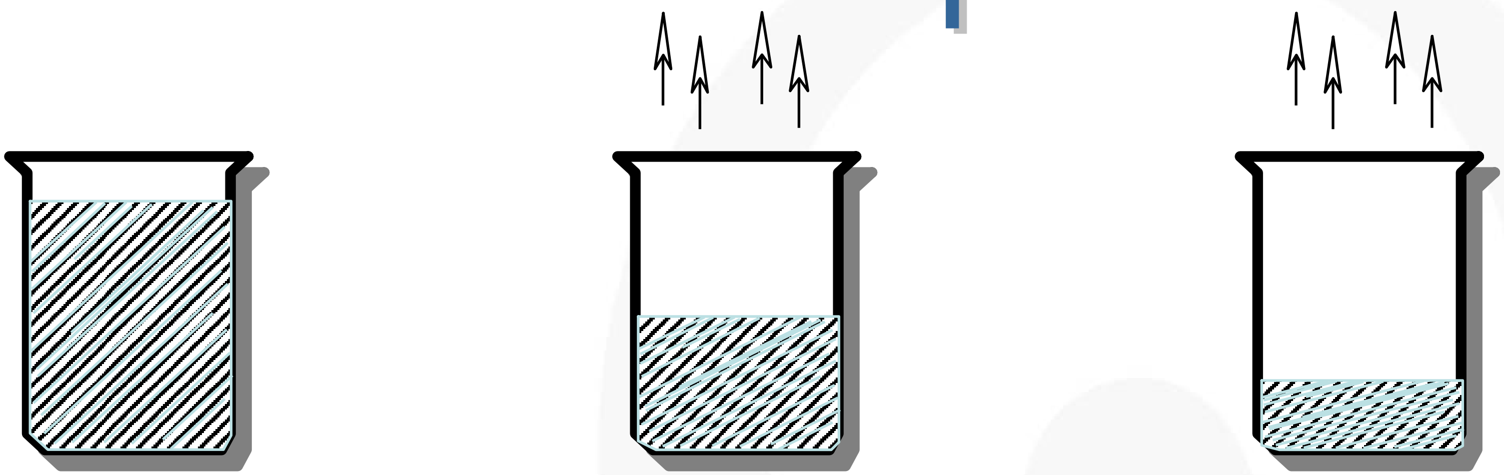
CYCLE OF CONCENTRATON – C.C

Evaporation



Before Evaporation	**After Evaporation**	**More Evaporation**
Volume:1000 liter.	**Volume: 500 liter.**	**Volume: 250 liter.**
TDS: 100 ppm	**TDS: 200 ppm**	**TDS: 400 ppm**
Conc. Factor: 0	**Conc. Factor: 2**	**Conc. Factor: 4**

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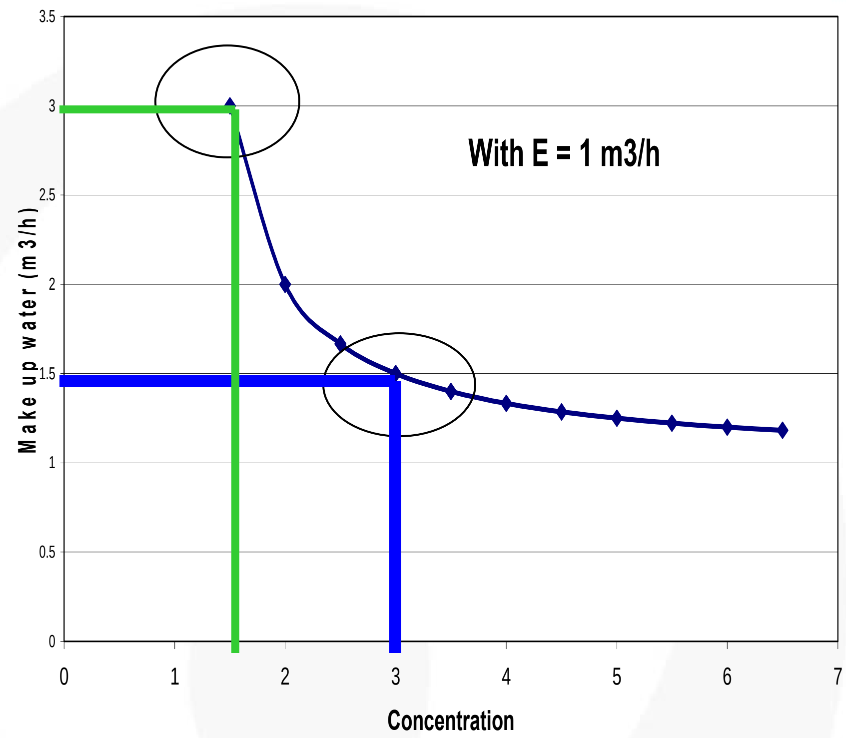
CYCLE OF CONCENTRATON – C.C

WHY CYCLE?

High cycles of Concentration Means :

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



WINDAGE

Definition :

The droplets of cooling water carried by the wind and lost from the system.

- **Windage is commonly calculated using the following equation.**

Windage = Re-Circulation Rate x 0.001

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EXAMPLE…

A cooling tower system currently circulates water at the rate of **10,000 GPM** and the cooling tower needs to cool the warmed water exiting the heat exchanger from **90ºF to 80ºF degrees** (or reduce the temperature of the water by 10ºF), TDS of make up water is **100 ppm** and cooling water **500 ppm.**

- **Calculate The Following :**
  - Evaporation Rate
  - Cycle Of Concentration
  - Blow-down Rate.
  - Windage.
  - Makeup Rate

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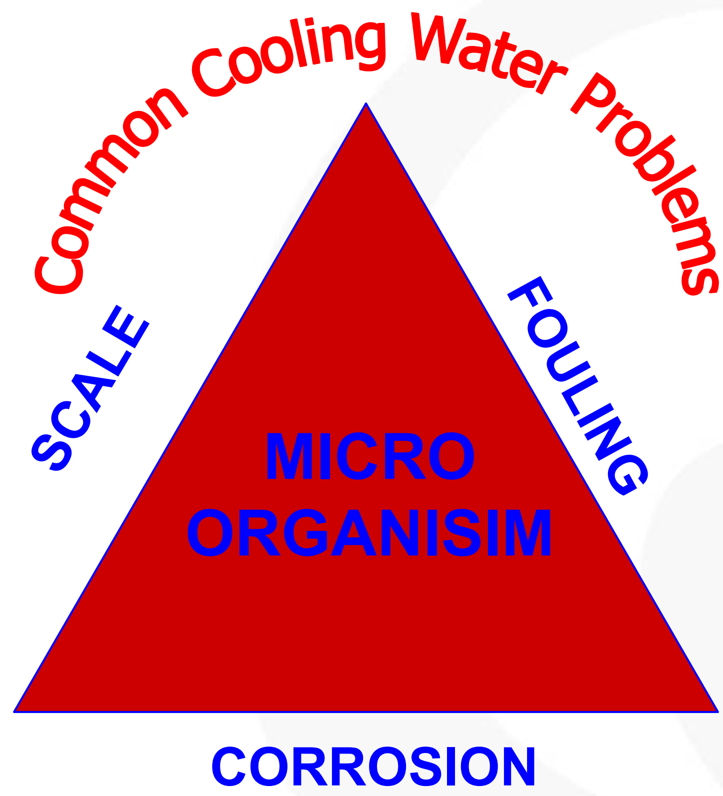
4. Basic Cooling Water Treatment principles

Water Treatment is the most important factor affecting the life and energy efficient operation of cooling towers equipments

COOLING SYSTEM WATER PROBLEMS



MINERAL SCALE

- Cooling Water contains many different minerals -- normally these minerals are dissolved in the water

- Under certain conditions minerals can come out of solution and form into hard, dense crystals called **SCALE**.

Precipitation

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COMMON SCALES

Scaled Heat Exchanger Tubes

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

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SCALING

Why is it so important to control it ?

SCALING

- **Insulating Film**
  - ↓ **Reduces Heat Transfer**
- **Blockage Of Tubes & Pipe works**
  - ↓ **Reduces Flow rate**
  - ↓ **Increase in Temperatures & Pressures**
- **Possibility Of Corrosion Under Deposit**
  - ↓ **Pitting**

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PARAMETERS AFFECTING THE RATE OF SCALE FORMATION

- PH
- TEMPRATURE.
- CONCENTRATION OF IONS e.g HCO_3^- , Ca^{+2} , Mg^{+2}
- Total Dissolved Solids.

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PARAMETERS AFFECTING THE RATE OF SCALE FORMATION

THE SEQUENCE OF EVENTS THAT LEADS TO THE CRYSTALLISATION OF A SALT MAY BE DEFINED AS :

SCALE

CRYSTAL GROWTH

NUCLEATION

SUPERSATURATION

SOLUBALISATION

Water & Soluble Minerals

PARAMETERS AFFECTING THE RATE OF SCALE FORMATION

HYDREX™ ANTISCALANT CHEMICAL ADDITIVES.

(MECHANISM TO CONTROL SCALE DEPOSITION)

1. THRESHOLD EFFECT

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

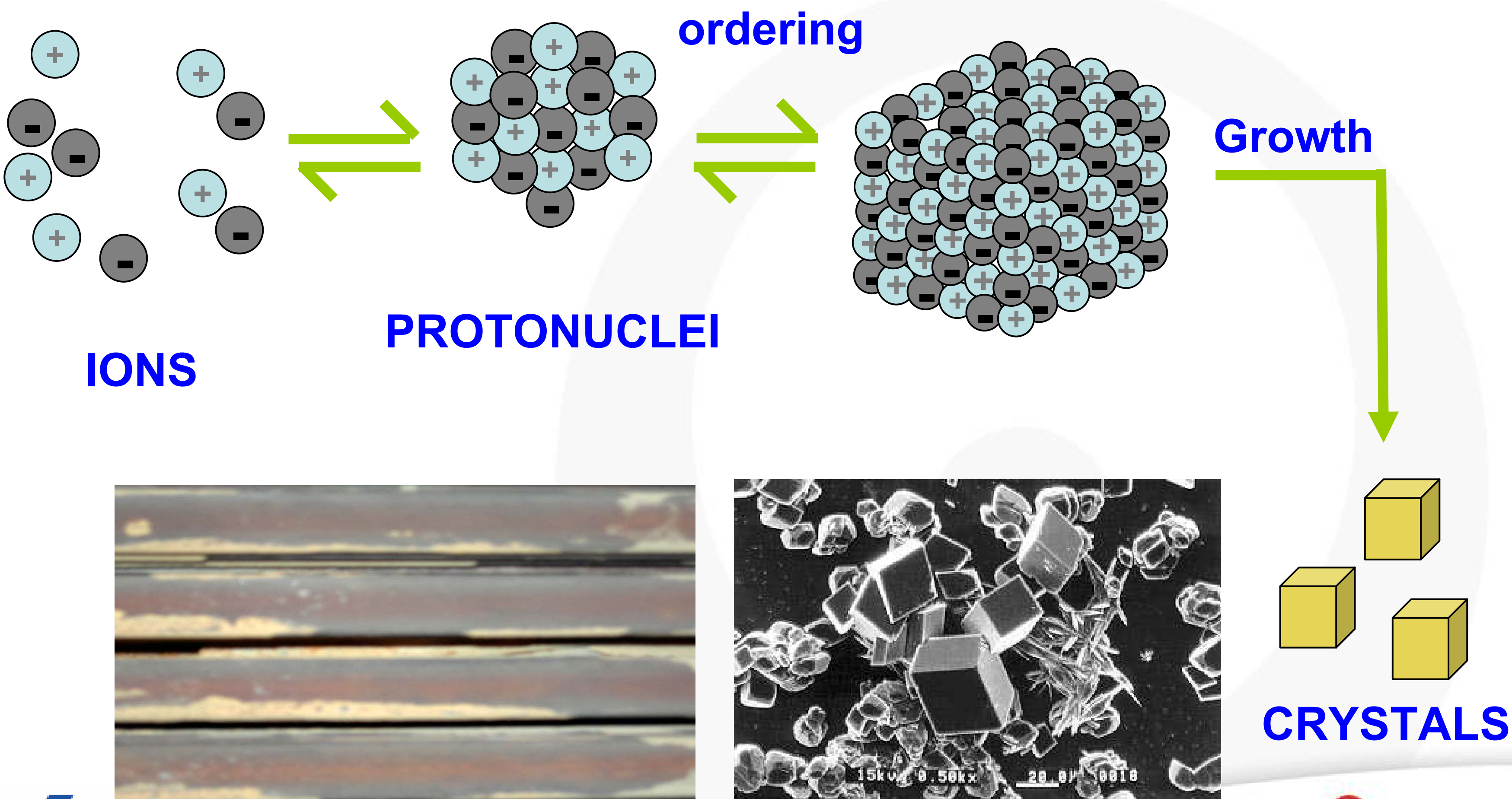
2. CRYSTAL GROWTH INHIBITION / CRYSRAL DISTORTION.

Chemical interference to normal crystal growth produces irregular crystal structure with poor scale forming ability

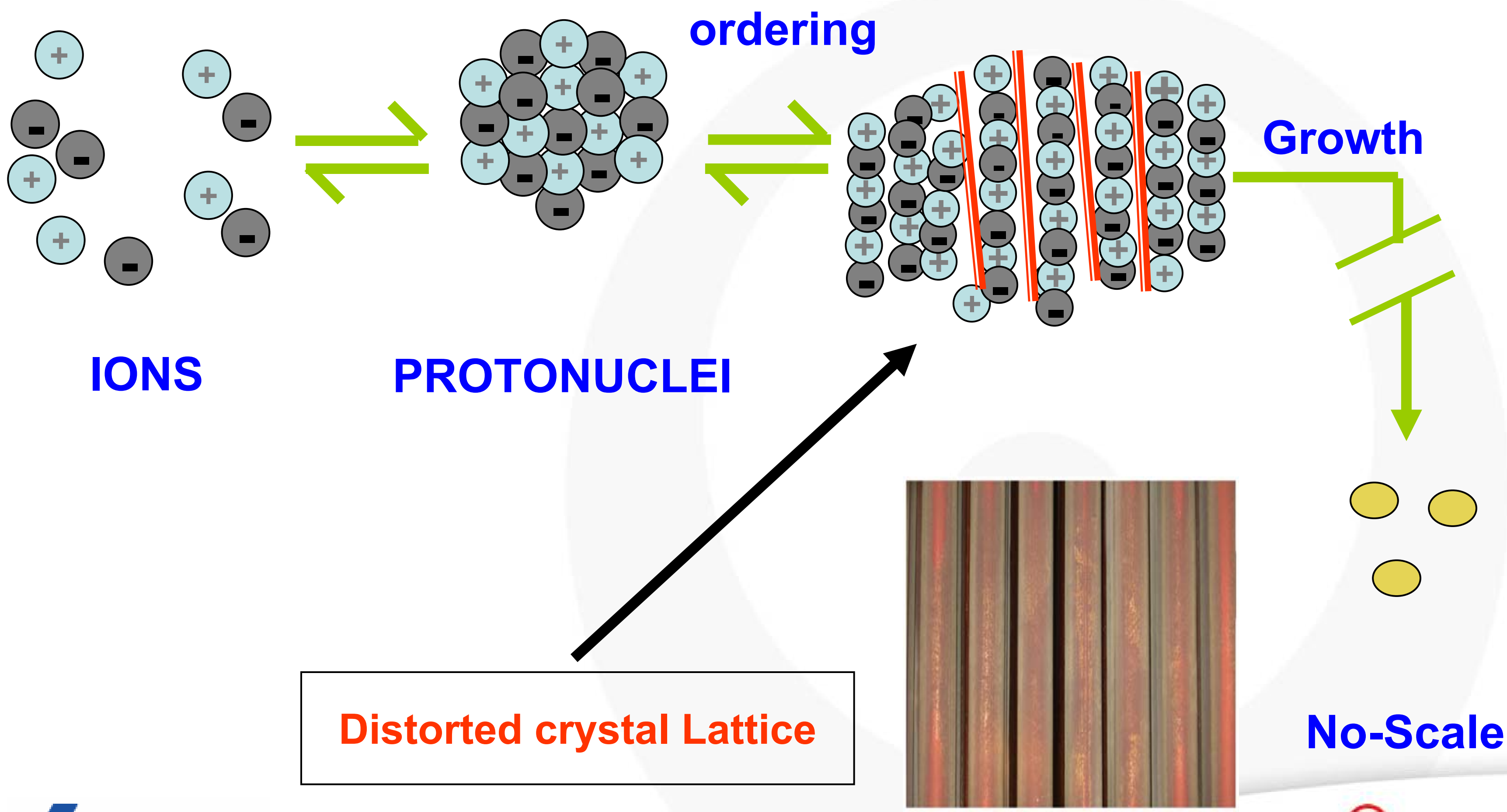
3. DISPERSANCY :

Chemical which can adsorb onto scale surface causing the particles to remain in suspension.

METHOD OF CONTROLING SCALE FORMATION



METHOD OF CONTROLING SCALE FORMATION



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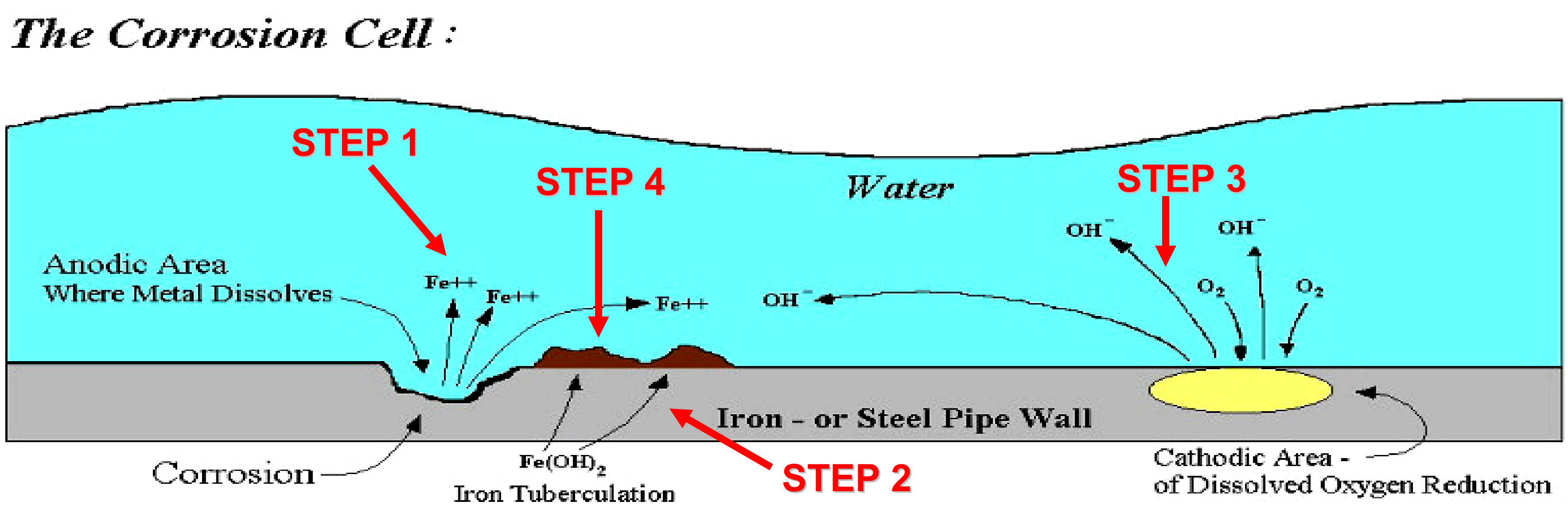
FOUR STEP CORROSION MODEL



- **Step 1**: At the anode, pure iron begins to break down in contact with the cooling water.
- **Step 2**: Electrons travel through the metal to the cathode.
- **Step 3**: At the cath ode, a chemical reaction occurs between the electrons and oxygen in cooling water to forms hydroxide.
- **Step 4**: Dissolved minerals in the cooling water complete the electrochemical circuit back to the anode.

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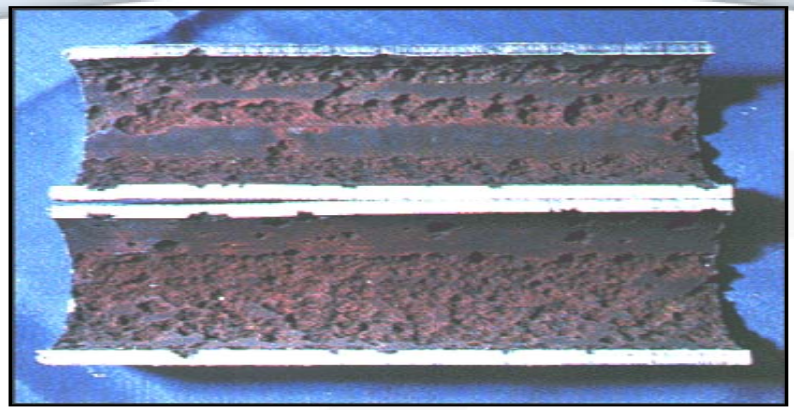
CORROSION



Corrosion product
Cooling Tower Circulation Pump

Corrosion product
Cooling Tower Suction Line

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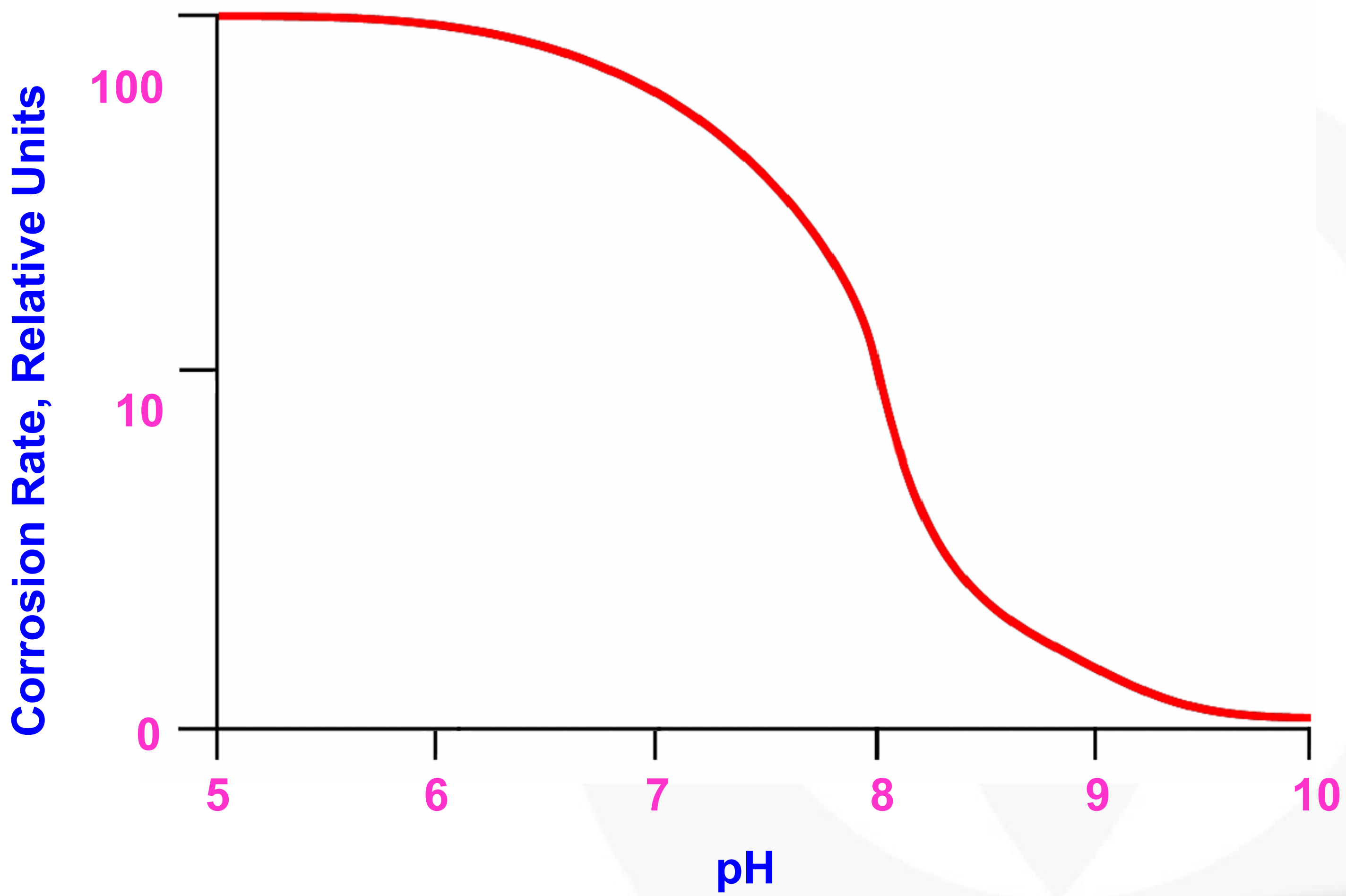
CORROSION

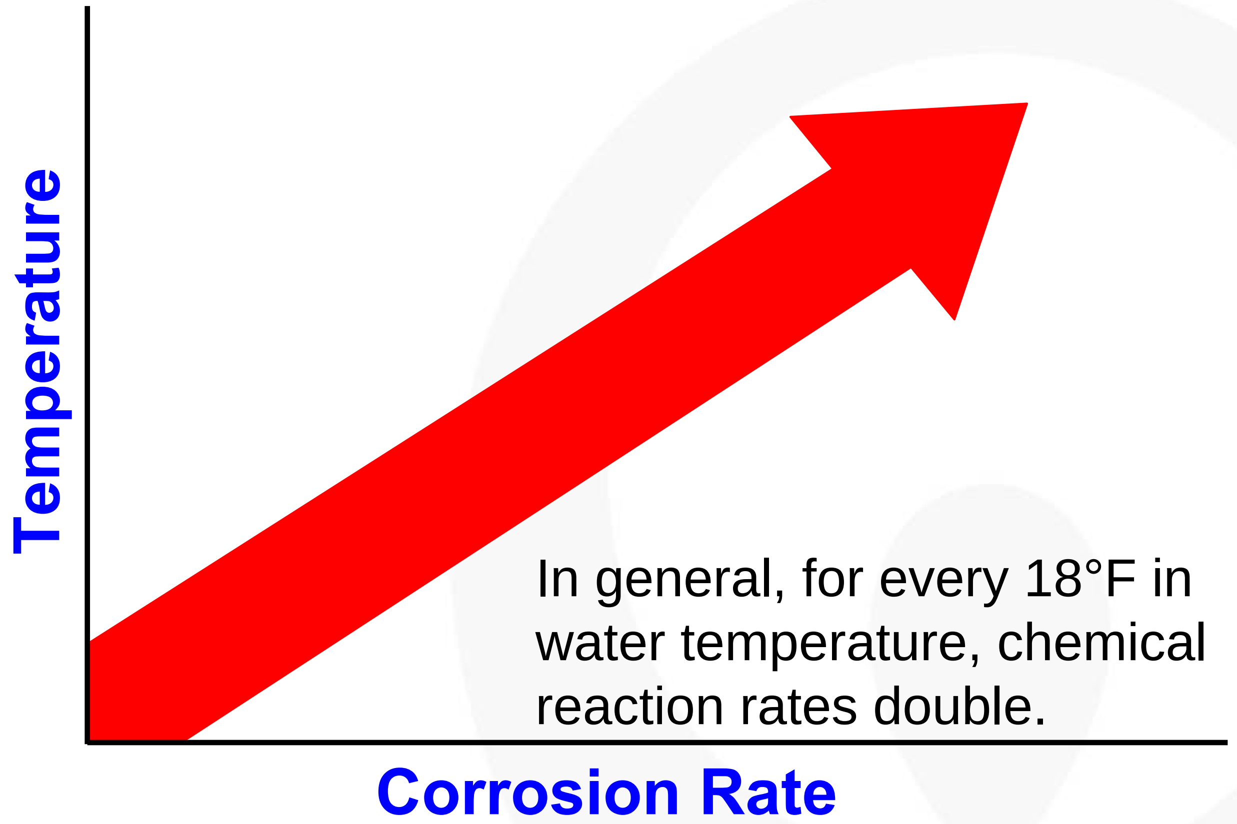
➢ Factors affecting corrosion rate

- Temperature
- pH
- Water velocity
- Product Solubility
- Metallurgy

CORROSION VS. WATER PH



CORROSION VS. WATER TEMPERATURE



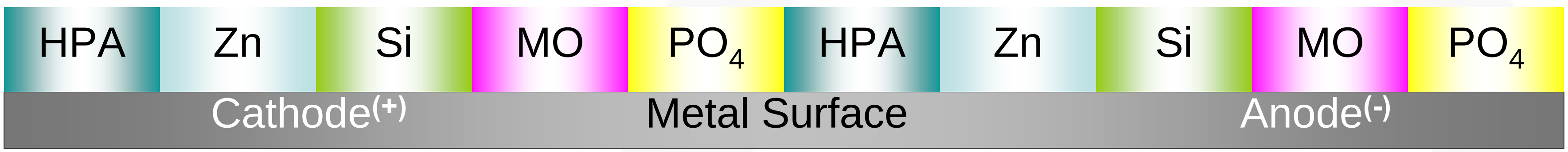
In general, for every 18°F in water temperature, chemical reaction rates double.

Corrosion Control

Common corrosion inhibitors for open cooling water systems:

- Molybdate
- Zinc
- HPA (all organic)
- Silicate
- Phosphate
- Polyphosphates

Corrosion Inhibition



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METHODS TO CONTROL CORROSION

❖ HYDREX^{TM} CORROSION INHIBITOR

ACTIVE MATERIALS	FUNCTION
MOLYBDATE	Anodic Corrosion Inhibitor
ZINC	Cathodic Inhibitor
ORGANIC INHIBITOR	Copper Metal Corrosion Inhibitor

METHODS TO CONTROL CORROSION

Two Types Of Corrosion Inhibitors :

1. ANODIC INHBITOR (MOLYBDATE).

- ✓ **Protect bulk of metal surface by forming oxide film.**
- ✓ **PH control not required.**
- ✓ **Does not promote bacterial growth.**

2. CATHODIC INHIBITOR (ZINC).

- ✓ **Stifles the cathodic reaction.**
- ✓ **Prevents corrosion from proceeding ahead.**

Both the cathodic & anodic sites are protected to ensure low overall corrosion rates

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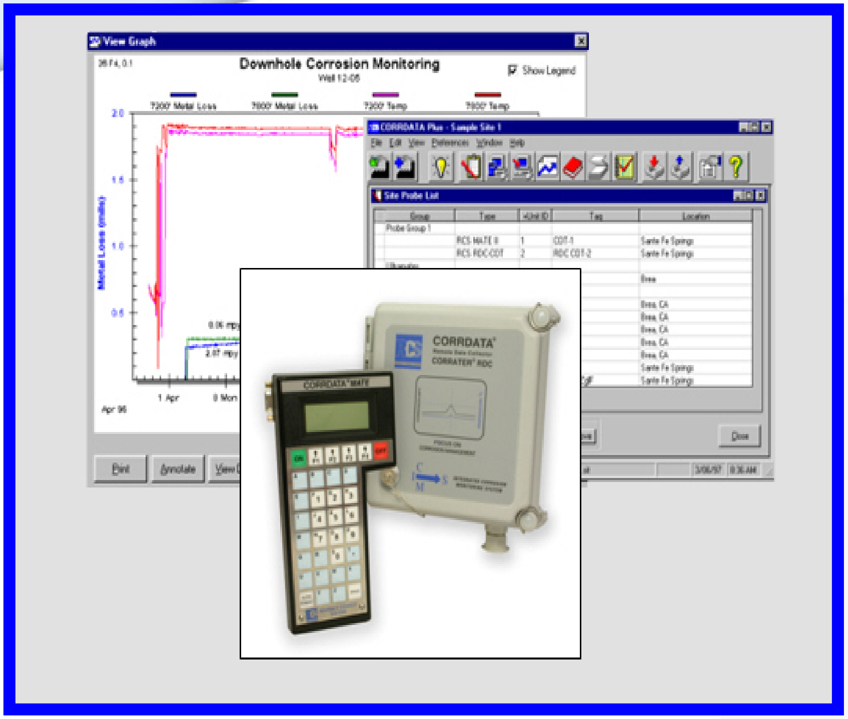
MONITORING TOOLS TO CONTROL CORROSION

Designed By

Metito/Veolia Water Solutions & Technologies

A. ON LINE CORRATER INSTRUMENT



- CORROSION RATE SYSTEM DESIGNED FOR COOLING WATER SYSTEMS.
- MEASURMENT OF CORROSION RATE (MPY) ON CONTINOUS BASIS.
- DATA LOGGING WITH CORRDATA PLUS SOFTWARE

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B. CORROSION & DEPOSITE MONITORING SYSTEM

THIS SYSTEM CAN BE USED BY METITO/VEOLIA WATER TO MONITOR AND CONTROL CORROSION / DEPOSIT IN HEAT EXCHANGER.

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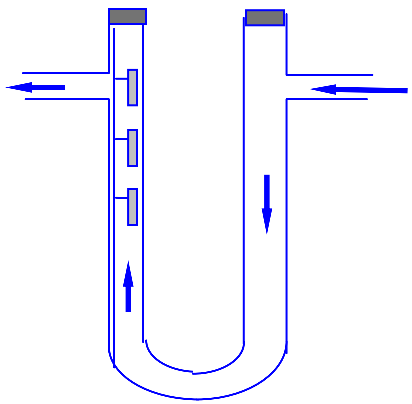
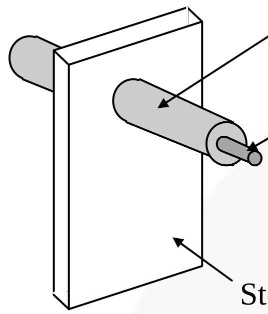
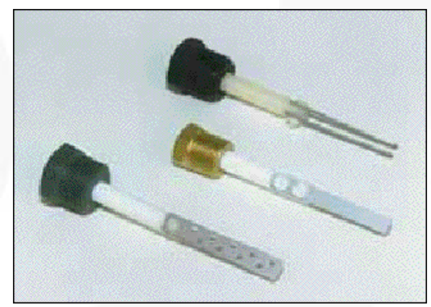
C. CORROSION COUPONS







$$C\ (\mu m/year) = \frac{\Delta w\ (g) \times 365}{Area\ (mm2) \times N(days) \times density\ (g/cm2)}$$

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5.0 MICRO-BIOLOGICAL CONTAMINATION

Micro-Organism Contamination caused by.....

- **BACTERIA (MICROSCOPIC ANIMALS)**
  - Aerobic
  - Anaerobic
- **ALGAE (MICROSCOPIC PLANTS)**
- **Fungi/yeast ('timber-eaters')**

ALGAE

- Large quantities of polysaccharides (slime) can be produced during algal metabolism.
- Plug screens, restrict flow and accelerate corrosion.
- Provide excellent food source.
- Exist between 5 to 65 C and pH 4 to 9.

FUNGI

- Although yeast and some aquatic fungi are normally unicellular, most fungi are filamentous organisms
- Fungi form solid structures which can reach a considerable size.
- Fungi require presence of organic energy source.
- Exist at between 5 to 38 C and pH 2 to 9 with an optimum of 5 to 6.

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EFFECTS OF MICROBIAL GROWTH

- Fouling of: tower, distribution pipework, heat exchangers
- Reduction in heat transfer efficiency
- Lost production
- Under deposit corrosion
- Inactivation/interference with inhibitors

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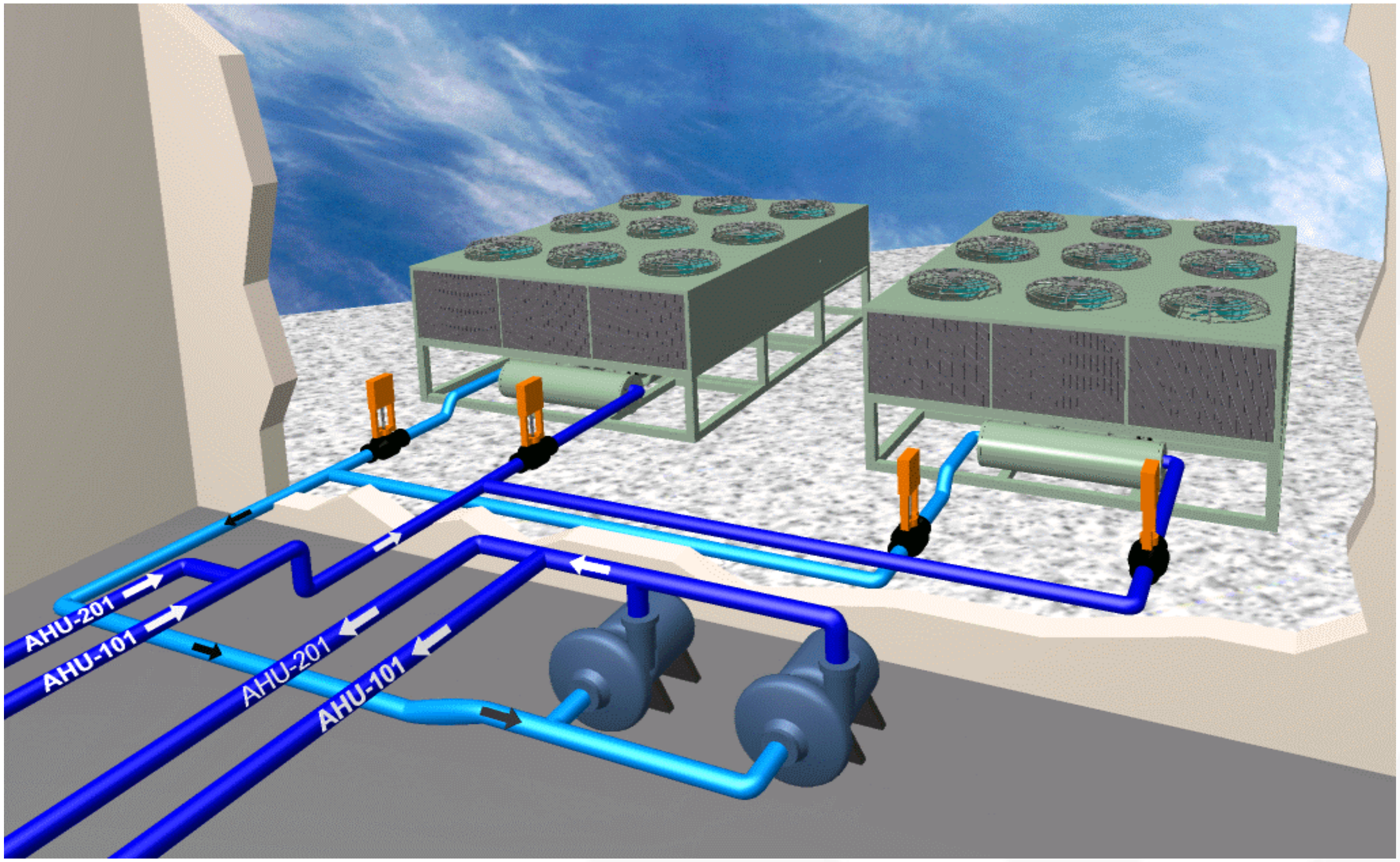
FACTORS CONTRIBUTING TO MICROBIAL GROWTH

- Rate of incoming contamination
- Amount of nutrient present
- pH
- Temperature
- Sunlight
- Availability of oxygen/carbon dioxide
- Water velocities

Closed Systems

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

CLOSED LOOP



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 Systems

Treatment objectives:

- Prevention of deposits from corrosion by-products
- Prevention of microbiological fouling (glycol can be a nutrient)

Water Treatment

- Corrosion Inhibitors
  - Nitrite-Borate-Triazole
  - Nitrite-Polyphosphate
  - Molybdate-Borate-Triazole
- Oxygen Scavenging
- Side-Stream Filtration
- Microbiological Control
- Glycol Systems and pH

Sodium Nitrite

- $NaNO_2$
- Sodium nitrite is an oxidizing agent which functions as an anodic inhibitor by forming an impervious oxide film to protect the metal from further attack.
- Layer is formed by the combined action of nitrite and dissolved oxygen and then kept in repair by the nitrite alone.

Silicates

- Sodium silicate (CAS Number 1344-09-8) is the generic name for a series of compounds derived from soluble silicate glasses and described as water solutions of sodium oxide (Na_2O) and silicon dioxide (SiO_2).
- The ability to change the proportion of silica to sodium and the solids content provides us with products of widely different functional and handling properties.

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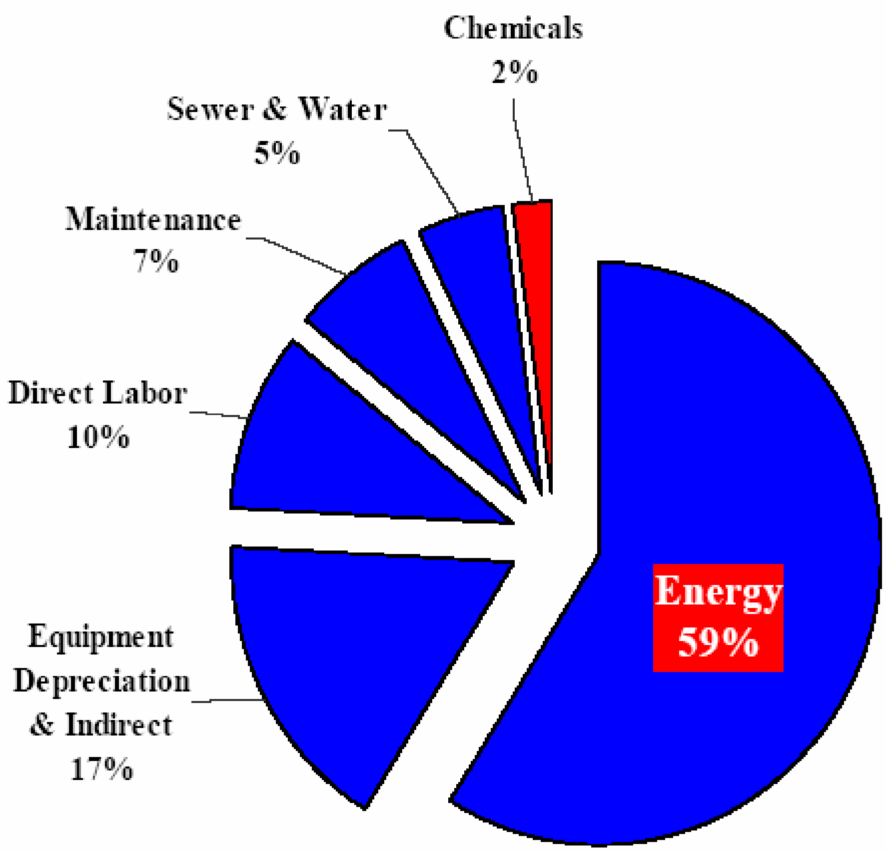
Azoles

- The most widely used azole in water treating is **tolyltriazole (TT).** Also used are **benzotriazole (BZT)** and **mercaptobenzo-thiazole (MBT).**
- While TT and BZT have roughly equivalent performance and stability, BZT costs more than TT.
- TT is about three times as effective as MBT and is much more stable to heat, oxidation, and light.



Conditions that drive up the cost of operation……

Scaling
Corrosion
Fouling
Microbial Growth

Poor Energy and Utility Management

Insufficient Preventative Maintenance

How Cooling Towers Work

Evaporation

- 1000 BTU's of heat are removed when one pound of water is evaporated.

- 75% of cooling is done by evaporation.

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How Cooling Towers Work

Convection

- Direct transfer of heat from the warm water to the cooler air.

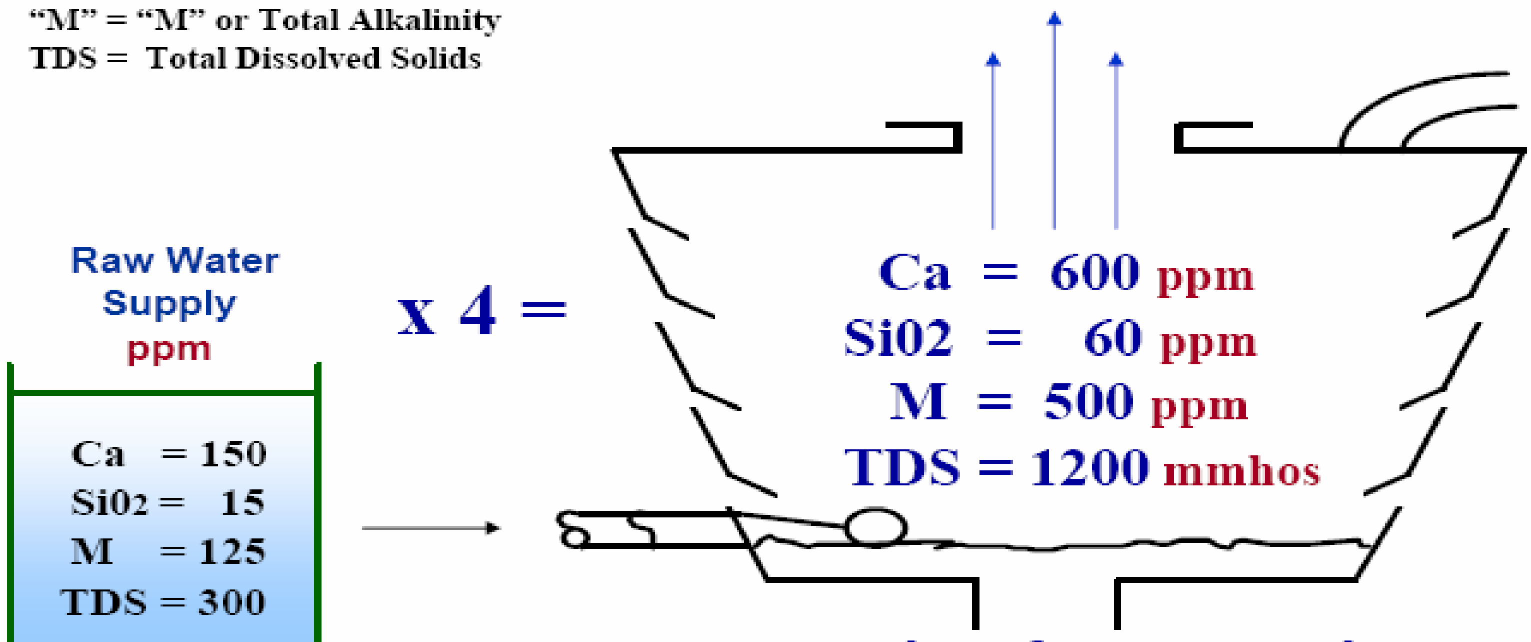
- Accounts for about 25% of the Cooling.

Cycles of Concentration

EVAPORATION & REPLACEMENT

Ca = Calcium Hardness
Si02 = Silica
"M" = "M" or Total Alkalinity
TDS = Total Dissolved Solids

Pure Water Evaporates
Minerals Left Behind



4.0 Cycles of Concentration

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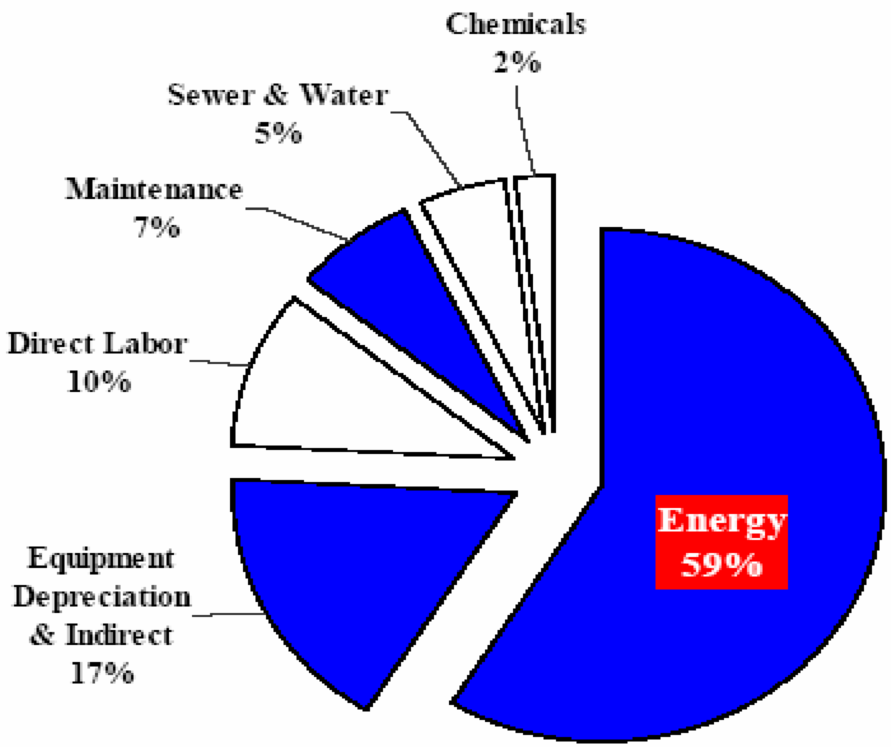
Cooling Cost Management - Scaling



Scaling related conditions that drive up the cost of energy use

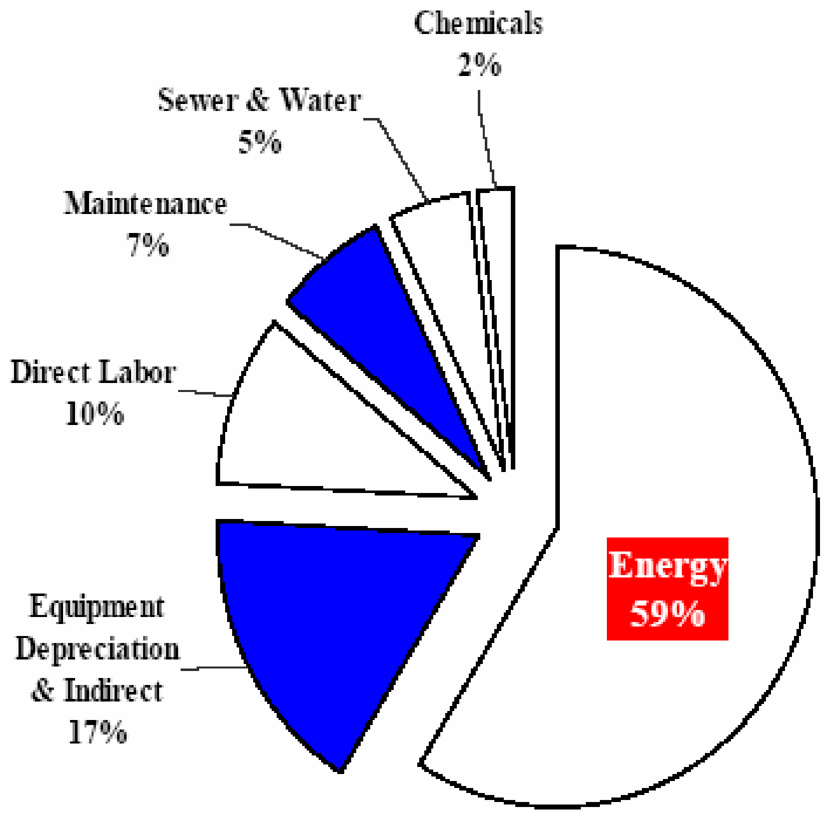
Primary:

Scaling - Reduces heat transfer, ultimately effecting efficiencies and energy usage

Secondary:

Systems have to work harder, causing shortened life expectancy of parts and systems

Cooling Cost Management - Corrosion

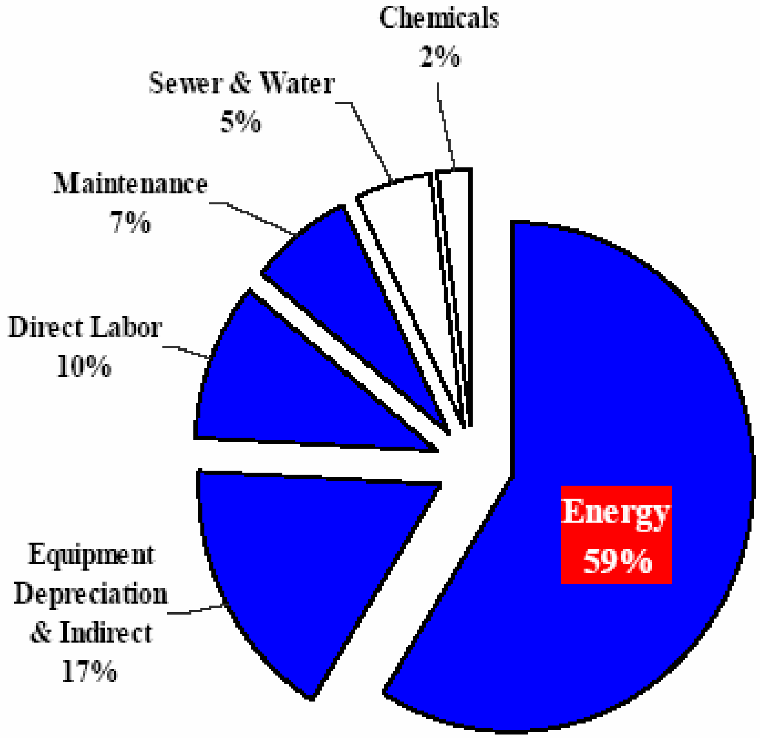


Corrosion related conditions that drive up the cost of operation

Premature replacement due to deterioration from corrosion

High Maintenance costs from damaged componant replacement

Cooling Cost Management
Micro-Biological Fouling



Micro-Bio related conditions that drive up the cost of operation

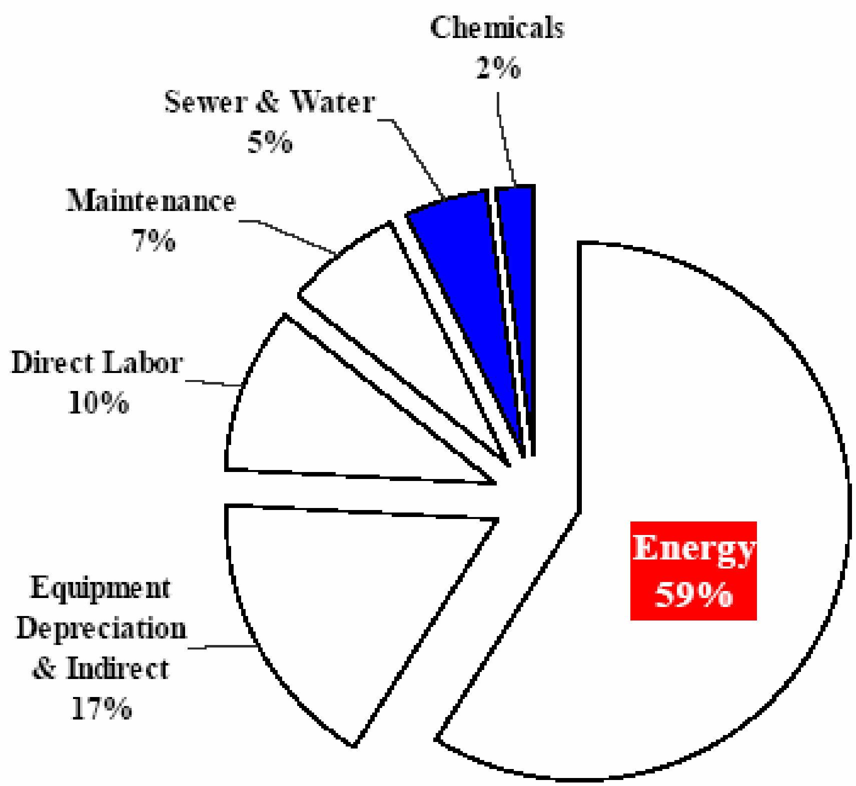
High energy costs due to insulative potential

Greater direct labor costs due to cleaning/hygeine requirements

Maintenance & Replacement costs due to associsated corrosion

Liability due to potential health Impacts

Cooling Cost Management - Blowdown



Blowdown related conditions that drive up the cost of operation

High water use/waste

Excessive chemical consumption

- Recirculation Rate.
- Temp at C.T Top.
- Temp at C.T Sump.
- Max Skin Temp (Condenser)
- C.T Lood.
- M.U Rate m^3/day
- Blow down Rate
- Pre-treatment equipments
- Current Treatment
- Current Dosing System
- Current Monitoring

Description	Make-up	Cooling
pH		
TDS		
Total Hardness		
Calcium Hardness		
Cl^-		
Total Alkalinity		
Fe		

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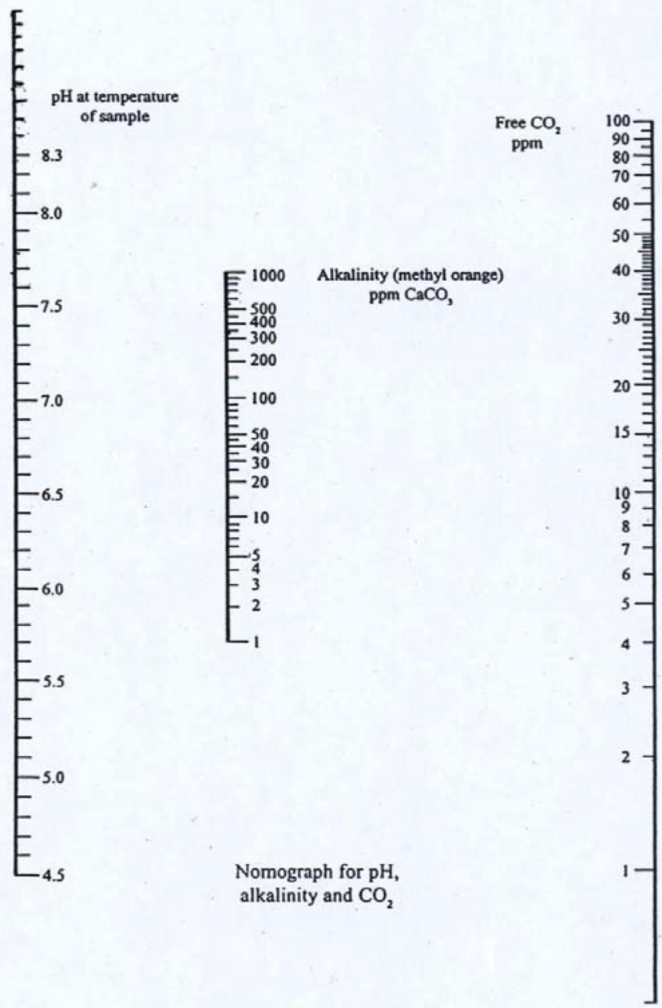
Total solids ppm	Ns
50 - 400	0.1
400 - 1000	0.2
1000 - 5000	0.3

Water Temp. °C	°F	Nt	Calcium Hardness ppm $CaCO_3$	N_h	Total Alkalinity ppm $CaCO_3$	N_a
0	32	2.6	18	0.9	18	1.3
2.5	36	2.5	23	1.0	23	1.4
6.8	44	2.4	28	1.1	28	1.5
10	50	2.5	35	1.2	36	1.6
14.5	58	2.2	44	1.3	45	1.7
18	64	2.1	56	1.4	56	1.8
22	72	2.0	70	1.5	70	1.9
28	82	1.9	88	1.6	88	2.0
32	90	1.8	111	1.7	111	2.1
38	100	1.7	139	1.8	140	2.2
44	112	1.6	175	1.9	177	2.3
51	124	1.5	230	2.0	230	2.4
57	134	1.4	280	2.1	280	2.5
64	148	1.3	350	2.2	360	2.6
72	162	1.2	440	2.3	450	2.7
			560	2.4	560	2.8
			700	2.5	700	2.9
80		1.1	870	2.6	880	3.0
			1050	2.7		
90		1.0				
100		0.9				

$pHs = (9.3 + N_s + N_1) - (N_h + N_a)$

$LSI = pH - pHs$

$pHs = 9.3 + (N_s + N_t) - (N_h + N_a)$



Nomograph for pH, alkalinity and CO_2

CONCENTRATION FACTOR

1	For normal M.U water	: Max Lsi 2.5
2	Softned or R/O M.U water	: Max S.S is 100

- For Low S.S use C = 10
- For High S.S use C = 5

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COOLING TOWER CALCULATION

$$\text{Evaporation Rate (E)} = \frac{0.01 \times \Delta T\ ({}^{0}C) \times R}{5.5}$$

$$\text{Blow Down} = \frac{E}{C-1}$$

$$\text{Windage} = 0.001 \times R$$

$$\text{M.U} = E + B + W$$

TREATMENT PROGRAMME

- Corrosion control
- Scale control
- Suspended Solids Control
- Microbiological Control

Testing & Monitoring

Cooling Testing - What, Where & Why ?

Sample	Analysis	Reason
Makeup	T.D.S. Hardness Alkalinity	Cycle of Concentration
	pH	Scaling / Corrosive
Treated water (where applicable)	As above	To ensure correct operation of pre-treatment plant
Recirculating Water	T.D.S. Hardness Alkalinity	Cycles of concentration + scale formation
	Treatment reserve	High $\longrightarrow$ waste Low $\longrightarrow$ reduced protection
	Iron levels	High $\longrightarrow$ corrosion

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What if ? Cooling