

Modern Treatment Programmes Can Reduce Water Consumption in Cooling Towers

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Introduction:

Cooling towers are the single largest users of fresh water in most process industries. Treatment programmes to not only control corrosion and fouling of equipment but also to conserve water have become a high priority.

This paper looks at some of the key reasons that limit cycles of concentration in a cooling water system and the modern treatment programmes that overcome these limitations.

Cooling Tower Basics:

A cooling tower rejects heat energy to the atmosphere primarily by evaporation of a small quantity of re-circulating water. The latent heat required for evaporation is drawn from the rest of the water that cools down. Typically, evaporation rates range from 1.0 – 1.5 % of the re-circulation water.

Evaporation of water also leads to an increase in the Total Dissolved Solids (TDS) of circulating water. The concentration of these dissolved solids determine extent of corrosion, scaling and fouling.

The water balance of a cooling tower are governed by following formulae:

$$E \text{ (M}^3\text{/Hr)} = \frac{\text{Re-circulation Rate (M}^3\text{/Hr)} \times \Delta T \text{ (}^\circ\text{C)} \times 1.8 \times F^*}{1000}$$

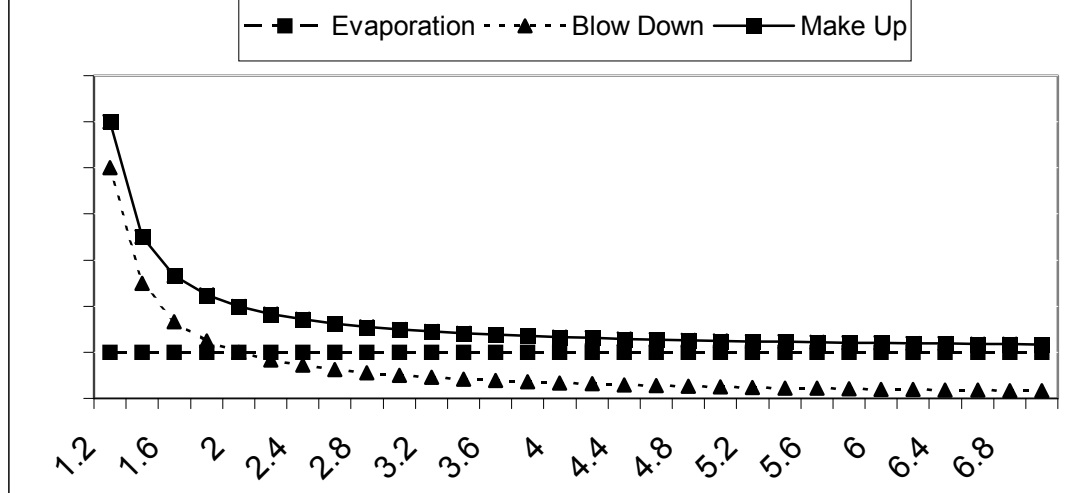
$$\text{CoC} = \frac{\text{Concentration of an impurity present in Re-Circulating Water}^{**}}{\text{Concentration of same impurity present in Make Up Water}}$$

$$\text{Blow Down (M}^3\text{/Hr)} = \frac{\text{Evaporation Losses (M}^3\text{/Hr)}}{\text{CoC} - 1}$$

*: Tower factor, the correction that needs to be made to compensate sensible heat exchange.

** : The impurity should be such that it is not affected by normal operation of the cooling water system, is not added to the system by way of treatment or contamination or removed from the system because of precipitation.

As can be seen readily, it is the CoC of a system that determine the water losses from a cooling tower. Higher the CoC, lesser are the losses and higher the concentration of salts in water.



The key to modern cooling water treatment practices is to operate the systems at high CoC without allowing corrosion and fouling problems to go out of control.

Key Water Quality Parameters affected by CoC:

As CoC increase, concentration of all salts and other impurities tend to increase proportionately. The key parameters that need to be taken account of are Calcium Hardness,

Chlorides, Silica and Holding Time Index (HTI). The limits used conventionally are tabulated at the end along with control limits possible now.

1. Calcium Hardness:

As calcium hardness increases, many conventional scale inhibitors such as HEDP begin to lose their effectiveness. Rather than control scale formation, the Ca-HEDP complex itself begins to precipitate and form a scale. Also, with increasing hardness levels, the scaling potential increases and the load on scale inhibitors also increases. This effect is further amplified in the discussion on HTI later in the paper.

effects of stainless steel are also well documented and are not repeated here. Essentially these are aggressive ions capable of penetrating passivating films and capable of interfering with the passivation process itself. Usually systems with significant SS equipment limit the chloride levels anywhere between 150 to 300 ppm as Cl^- . Very often, this forms the basis for limiting CoC of such systems.

3. Silica:

Silica is present in all naturally occurring sources of water. Its solubility is usually high enough (120 to 160 ppm) in the near neutral pH ranges that most cooling water systems operate at. Silica also exhibits normal solubility i.e. increased solubility with increased temperature. However, if silica solubility is exceeded, the scales that form are almost impossible to remove.

Consequently, all cooling water systems operate below the solubility limit of silica as a precaution. In many cases, it is Silica that is the limiting factor for increasing cycles of concentration.

4. Holding Time Index:

HTI denotes the time in which 50% of the water in the system will be replaced with fresh water. As HTI becomes high:

The time for which a dispersant has to delay precipitation of salts becomes higher
Bacteria have longer time to adapt themselves to system conditions, biocides, etc.
Greater accumulation of dirt takes place in the system

Systems with high HTI are therefore more prone to fouling than systems that operate at lower values. These systems require more stringent attention to corrosion, fouling and microbial growth.

IEI's range of products are designed to specifically address these problems so that cooling water systems operate consistently at high CoC.

Essentially, this has been achieved through

New generation dispersants and phosphonates that have calcium tolerance levels in excess of 1000 ppm as CaCO₃,

Molybdate based corrosion prevention programmes that handle chloride levels of 2000 ppm, Silica inhibitors that can keep up to 300 ppm silica in solution and,

A thorough understanding of dispersant chemistry so that HTI levels of even 240 hours have been handled successfully.

Effective Dispersants – the Key to Modern Cooling Water Programmes:

Dispersants basically function as poly-anions. The high negative charge on them destabilizes the normal precipitation mechanism in a cooling water system. By providing a more negatively charged site, the scale forming cations such as Ca⁺⁺, Fe⁺⁺⁺, etc are attracted to them preferentially. Sufficient dosage of dispersant (sufficient in proportion to the hardness / dissolved Fe / TDS) is essential. Under dosing will cause the dispersant to get “exhausted” in a short time.

The other key properties of a dispersant are its molecular weight and the molecular weight distribution (distribution co-efficient). Too low a molecular weight will not impart sufficient anionic charge on the dispersant whereas, too high a molecular weight will cause too many cations to migrate and attach themselves to the dispersant. By having dispersants in the correct molecular weight range, the dosage can be fine tuned and maintained consistently. Often, poorly manufactured dispersants can have a broad molecular weight range where only a small percentage of the dispersant is in the ‘usable’ range and the rest is inert or worse, detrimental to the system.

IEI's dispersants have been designed with above criteria i.e. high tolerance to Ca/Fe/Zn and a very low distribution co-efficient so that the entire quantity of dispersant added to water is utilized.

Effect of Molybdate on Controlling Chloride Corrosion:

high chloride ion concentration in cooling water systems.

The effect of these modern treatment programmes on water consumption will become obvious from the cases cited below:

Cement Plant in Andhra Pradesh:

Make Up Water Quality:		Plant Details:	
pH:	7.8 – 8.0	Max Water Temp:	54 – 56 °C
Total Hardness:	250 – 300 ppm as CaCO ₃	Holding Time Index:	8.6 Hours at 2 CoC
Ca Hardness:	200 – 250 ppm as CaCO ₃		43 Hours at 6 CoC
Alkalinity:	250 – 300 ppm as CaCO ₃	Extreme water scarcity area Low HTI enables low levels of dispersants to be used	
Chloride:	40 – 60 ppm as Cl ⁻		
Silica:	40 – 60 ppm as SiO ₂		

A conventional treatment programme would have operated at best at about 2 cycles of concentration beyond which scale formation would have been uncontrollable. The only method of increasing CoC would have been to install a softener with consequent capital costs and increased operating costs for regeneration, manpower etc..

IEI had in fact received an order for supply and installation of a softener. After discussions with the customer, the softener order was recommended to be cancelled and instead a new generation treatment that operated at 5 – 6 cycles of concentration was started.

pH	7.2 – 7.6	Silica	90 to 110 ppm as SiO ₂
Ca Hardness	1700 to 2000 ppm as CaCO ₃	Chloride	< 250 ppm as Cl ⁻
Total Hardness	2300 to 2700 ppm as CaCO ₃		

Water Balance		Performance
Blow Down at 2 CoC	24.2 m ³ /hr	No scales after 10,000 hours of continuous operation
Blow Down at 6 CoC	4.84 m ³ /hr	Corrosion rate 1 – 3 mils per year

Performance:

Water Saved: 1,69,600 m³/year.

The treatment programme continues till date (uninterrupted since 1997) with satisfactory performance.

Combined Cycle Power Plant in South India:

Make Up Water Quality:		Plant Details:	
pH:	8.2 – 8.5	Re-circulation Rate:	3000 M ³ /Hr
Total Hardness:	150 ppm as CaCO ₃	Cooling Range:	10 deg C
Ca Hardness:	50 ppm as CaCO ₃	CoC Designed	4
Chloride:	800 ppm as Cl ⁻	Admiralty brass and SS equipment	
Silica:	< 10 ppm as SiO ₂	Extreme water scarcity area	
Conductivity:	2800 µs/cm		

With a conventional treatment, using this water would not have been possible at all. At best this system would have operated at 1.5 CoC. IEI's molybdate treatment operated at the design Cycles with complete control over corrosion, scaling and fouling.

Chloride < 2200 to 4000 ppm as Cl⁻

(Varied with variation in make up quality, mostly above 3000 ppm)

Water Balance		Performance achieved
Blow Down at 1.5 CoC	43 m ³ /hr	Corrosion Rate on MS: 2 – 5 mils / year
Blow Down at 4.0 CoC:	14.5 m ³ /hr	Corrosion Rate on SS: Not detectable Corrosion Rate on Admiralty Brass: < 0.5 mils/year

Water Saved: 2,67,000 m³/year

Summary and Conclusion:

A comparison of the broad ‘windows of operation’ of the earlier treatment programmes and the modern programmes will clearly demonstrate the difference between the two. Users of conventional programmes can readily estimate the savings in water and treatment chemicals for their cooling water systems.

Parameter	Conventional Programmes	Modern Programmes
PH	7.0 – 8.3	6.8 – 9.2 (Overall range, each programme has a specific narrower range)
Ca Hardness	300 ppm as CaCO ₃ , occasionally up to 600 ppm as CaCO ₃	800 – 1200 ppm as CaCO ₃
Chloride	150 – 300 ppm as Cl ⁻	1500 – 2000 ppm as Cl ⁻
Silica	140 – 160 ppm as SiO ₂	140 – 180 ppm as SiO ₂ without silica inhibitors 300 ppm as SiO ₂ with silica inhibitors
Holding Time Index	Max 120 Hours	More than 200 hours

The modern cooling water treatment programmes have evolved to a stage where blow down losses can be reduced to a great extent without compromising on performance. Very often this can be achieved even without resorting to expensive pre-treatment equipment.

