MANAGING OF COOLING CIRCUITS IN THE REFRIGERATING CHAIN.

INDICATIONS TO PRESERVE WATER COOLING SYSTEMS EQUIPMENT HAVING THE LOWEST ENVIRONMENTAL IMPACT.

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The correct treatment of waters, inside industrial cooling systems and in any industry that uses it for production, implies an accurate knowledge of the main characteristics of *process and water*, of peculiar behaviours according to different productions and, most of all, of which technologies should be used in order to solve problems.

This means that technical interventions able to globally monitor problems and to solve them by using the right technologies should be performed, in order to avoid interferences or process unbalances that may be imputed to water and its treatment. Also additives and technologies aiming to obtain quality and effectiveness should be used.

The improving process of technical interventions, chemical and environmental treatments on water, should take into consideration a fundamental aspect: the respect for waste waters regulations. A part of cooling waters is discharged, often into superficial water courses, without being purified.

According to these conditions it is compulsory to adopt proper and not polluting treatments, as we will see in the following pages.

Problems correlated to water cooling systems' management.

Cooling systems linked to freezing groups are mainly composed by Carbon steel pipes, a tower group or evaporative condenser made by galvanized plate and heat exchangers made by Copper and its alloys; these metals are attacked by:

1) - corrosion and aggressive action of contained water, this impoverishes the equipment value and causes maintenance interventions due to the replacement of some parts or to their renewal.

2) – limestone scales on parts where the heat exchange is higher, parts like, for example, heat exchangers or parts of the circuit where water evaporates completely (edges of the tower's fill); this brings about a heat exchange loss, thus a loss of circuit's performances that obliges people manpower to make cleaning interventions and chemical washes.

3) – biological growth (algae, bacteria, slime) considering that 600 – 1000 m^3 of air are necessary to cool 1 cubic metre of water, so practically it has the same behaviour of an air-washing tower. This means that it gathers all the substances that are present in the air (ground, bacterial spores, leaves, pollen, sand, etc.) in the recycled water. A colonisation of algae and bacteria on entire surfaces often takes place, this brings about a reduction in heat exchange and pressure drops.
In our speech we will talk about the first two phenomena.

Water cooling of freezing groups

Heat coming from the industrial cooling process is disposed by using water, this is much more practical and cost-saving in comparison with the use of air.
The need of water for cooling and its higher and higher supply and disposal costs, pushes industries to save and optimise this resource.
Heat exchange in evaporative towers happens, besides for conduction and convention, through a process called *Mass transfer*.
This process takes place by air circulation, this helps a small amount of water to evaporate. The necessary heat for such passage of state is absorbed from the cycling water. This cools it down (latent heat of evaporation).

This phenomenon has a particular importance if we consider that transforming one litre of water into vapour requires approximately 600 Kcal, this means that the same are necessary to cool down of 6 °C 100 litres of water.

Typical application of the cooling tower

Circulating water, after having been cooled inside the tower, can be sent to:

a) Heat exchangers, where the product that has to be cooled (Ammonia, Freon, etc) circulates upstream water;

b) A condenser, where water cools the fluid that has to be used. Often In this case the heat exchanger is inside the tower group and is called "evaporative condenser"

In both cases, problems remain the same.

Water used inside equipment

According to rocks and ground that it permeated, rainwater forms plerotic or surface waters with a different mineralization degree and very different characteristics.

Carbon dioxide contained into rainwater reacts with rocks and calcareous ground, forming calcium and magnesium bicarbonate that correspond to water hardness; these two substances, according to the quantity of limestone they solve, becomes less aggressive and more scaling.

Several classifications exist to group different kinds of water into a few homogeneous categories, for example they are divided into very hard, hard, sweet, etc., or aggressive, balanced, scaling waters.

According to the analytical characteristics of a kind of water, we are able to determine before if it is corrosive or scaling, using some methods called as their inventors: Langelier and Ryznar index.

Normally when water enters an evaporative cooling system, its salts are concentrated and carbon dioxide is stripped. This makes the circuit's water increase its pH.

This influences the balance of Calcium Bicarbonate-Carbonate as showed:

$$Ca(HCO_3)_2 \longrightarrow CaCO_3 + H_2O + CO_2 \nearrow$$

The reaction moves to the right forming Calcium Carbonate (with a very low solubility), this substance precipitates forming scales together with Magnesium Salts.

We remind you that the cooling circuit water's pH value grows because it loses Carbon dioxide; this phenomenon (linked to the fact that the quantity of water discharged is lowered in order to save it, and this causes a growth of total salinity) creates another help for calcareous precipitation and, as we will see in the following chapter, an increase of corrosive phenomena.

Composition percentage of scales in cooling equipment (average values)

$CaCO_3$	71.5
Fe_2O_3	12.7
SiO_2	7.1
$Mg(OH)_2$	0.7
$CaSO_4$	0.5
Organic Substances	3.4

Influence of deposit formation on the heat exchange process

Type of deposit	Deposit's thickness	Total Coefficient of heat transfer calculated on the external diameter of the pipe BTU/ft^2 x h x °F*	Reduction of heat transfer speed
Clean surface	-	260	0%
Ferric oxyde	1/8" = 3.175 mm	22.2	91.8
Clay	1/8" = 3.175 mm	31.6	87.8
Calcium carbonate	1/8" = 3.175 mm	33.6	87.2

* 1 BTU/h ft^2 x °F = 4882.43 Kcal/m^2 h °C

Corrosive phenomena

Modern attitude is focused on using superficial treatments with Zinc layer to protect pipes but, often, this does not solve the problem of corrosion; the largest part of water cooling circuits have a tower or a galvanized evaporative condenser.

Very often, galvanization suffers from corrosive attacks from the water environment.

A thin and adherent added metal layer is much more elastic of a thick one, so it less easily “crackes”, thus better protecting the metal below but, as protection made by Zinc on Iron is anodic sacrificial, the related applied thickness is very important according to the long-lasting anticorrosive effect.

It is demonstrated that zinc protects itself forming a barrier by the corrosion process, under standard weather conditions, in presence of humidity and at not too high temperatures. However, this protection lacks because of the more and more frequent use of “softened” waters (decalcified) not correctly managed inside the circuit.

Taking Calcium away from water means eliminating a scaling agent (as previously seen), Calcium bicarbonate existing in nature is a very good corrosion inhibitor, so this change on the water balance brings about an increase in its aggressiveness against Zinc and Iron.

Another important aspect is due to recycled waters’ pH increase: decalcifying water, Sodium Bicarbonate stays inside the circuit, and, concentrating itself with water, reaches a very high pH and alkalinity. Zinc is not able to tolerate these conditions, especially if calcium protection is not present (it was eliminated before).

In this way, corrosion proceeds very quickly, the first rust formation is “white” because of salt concentration and alkalinity on the galvanized surface, after some months it is possible to see “red rust”, this means that pure zinc was consumed and that the middle Zinc – Iron layer or even the lower steel layer is being attacked.

The phenomenon above explained does not happen using moderately hard waters with an almost neutral pH: in this case the Zinc carbonate – hydroxide layer ($3Zn(OH)_2 * ZnCO_3 H_2O$) that is formed, differently from the “white rust”, is not porous and is a good barrier to corrosion: we would like to underline that the product appears only using softened water that causes a water environment with high alkalinity and low hardness (and often, due to salt concentration of the circuit’s water, is rich of Chlorides and Sulphates that are very corrosive ions).

How to manage circuits without problems due to water and following regulations for waste waters

First of all, let’s consider values for some parameters that should not be overcome during the cycle, of cooling equipment with tower or evaporative condenser, for waters treated with the suitable products:

Circuit parameter	Softened water	Raw water
Total hardness mg/l $CaCO_3$	10 – 50	300 – 600
pH value	8,0 – 9,0	< 9,1
Total alcalinity mg/l $CaCO_3$	150 – 300	250 - 400
Conductivity micro-Siemens	< 2500	< 1800
Chlorides + Sulfates mg/l	< 400	< 600

Chemical treatments following waste waters’ regulations

Modern technologies allow a good management of cooling circuits following regulations for waste waters’ elimination, so waters can be treated in order to avoid corrosions and scales. Then, these waters can be discharged directly into surface waters following regulations in charge.

It is recommended, anyway, to send these waters to a purifying equipment, in order to lower their environmental impact as much as possible.

a- Corrosion control

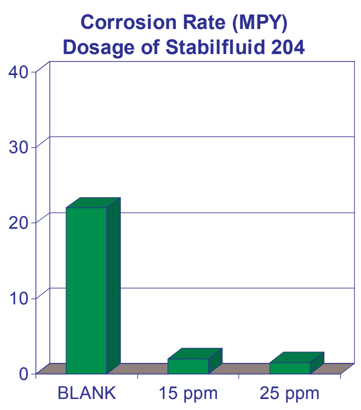
A new group of corrosion inhibitors has been studied to treat recycled waters inside cooling circuits fed with softened water or with aggressive characteristics towards the circuit's metals.

These substances are phosphonocarboxylic derivates that are present in the Stabilfluid series products. These products allow a very effective corrosion control and have a very low environmental impact.

Their effectiveness consists in forming a cathodic layer on surfaces in contact with water.

Traditional treatments that imply metals like Zinc and Molybdenum are kept under control, as regards waste waters, as well as classic treatments based on phosphates/polyphosphates/polymers because they bring along high quantities of Phosphorus to water, thus increasing the eutrophic phenomena in the sea.

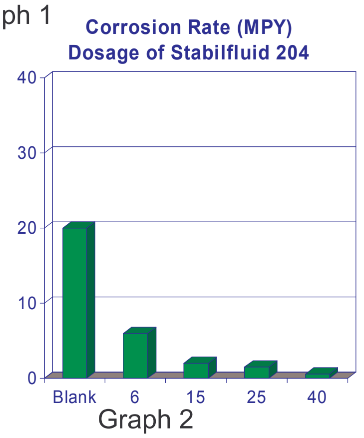
Phosphonocarboxylic derivates contain a functional group $-PO_3^{\ 2-}$ but the quantity of Phosphorus that remains in water is extremely low. They are extremely effective, so their dosage inside the water cycle is highly reduced. You may see that from the graphics below:



Graph 1

Waters' characteristics:

Total hardness	10 ppm $CaCO_3$ graph 1
	100 ppm graph 2
Temperature	35°C
pH	9,0



Graph 2

b – Scales and deposits control

By following developments made in the field of low-environmental impact anticorrosive treatments, as well as antiscaling and dispersing treatments, we have obtained products that can perfectly control scales and deposits by keeping a low environmental impact.

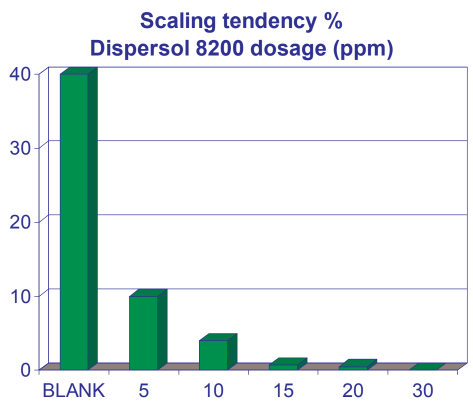
These products are part of carboxylates and acrylic co-polymers group (Dispersol series).

Their effect is to maintain a colloidal dispersion between micro particles of Calcium Carbonate, by avoiding their agglomeration and, consequently the precipitation, even under conditions of very high salinity, temperature and pH.

In this case it is possible to work also without Phosphorus compounds, so highly reducing the nutritional impact that this one has on the aquatic microflora.

So, traditional treatments, based on Phosphorus organic derivates, may be replaced in some cases, increasing performances.

The graphics indicated below shows the reduction of water's scaling tendency according to the dosage level of the antiscaling product.



Total hardness 560 mg/l $CaCO_3$

Total alkalinity 400 mg/l $CaCO_3$

PH value 9,1

Temperature 35°C

Environmental profile

Toxicological values of the products explained above are written hereunder:

LD_{50} 96 h (iris trout) > 1000 mg/Kg

EC_{40} 48 h (daphnia) > 1000 mg/Kg