AVGASAR OCH RENAR

Corrosion

In technical treatment systems
Reason and measures

Corrosion in technical water treatment systems

Corrosion on the inside of pipes and components in our most common liquid systems, heating and cooling systems, has increased a lot during the last 10–15 years. The damage costs the society billions every year in repairs and decreased energy transfers. Included in these costs is the industrial loss of productions when the technical water treatment systems break down or don't work as they were meant to do. Corrosion is a destructive or alteration in material because of the surroundings.

The most common liquids are water or a water based solution for example glycols or salts. Since water is a common component most problems are water related.

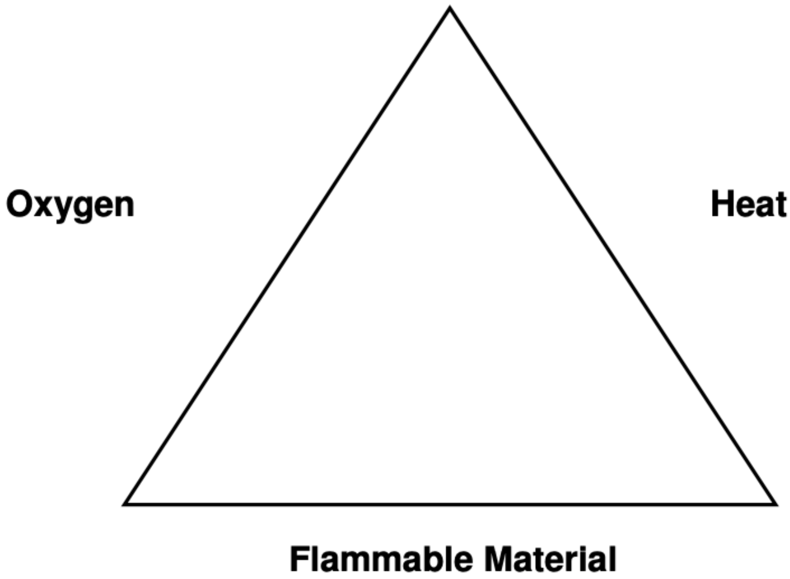
Water is a unique liquid with big capacity to dissolve or react with gas and solid materials, which often makes water the opposite of the pure liquid we often see it as.

Corrosion on a metal surface in contact with water is an electrochemical reaction between an ignoble and a more noble area. Between these areas a galvanic element is developed which release electrons from a metal surface and a galvanic electric flow is created between the surfaces. The size of the flow depends on the liquids ability to carry metal ions; it works like a battery liquid. (Cp. lead batteries oxidation/reduction process).
The liberated electrons react with other ions and oxygen, which flow loose in the liquid.
This process creates corrosion products (oxides) which set on the metal surface or flow with the stream in the system.
Depending on the amount of available oxygen and which material that's involved in the process there will be different oxides.

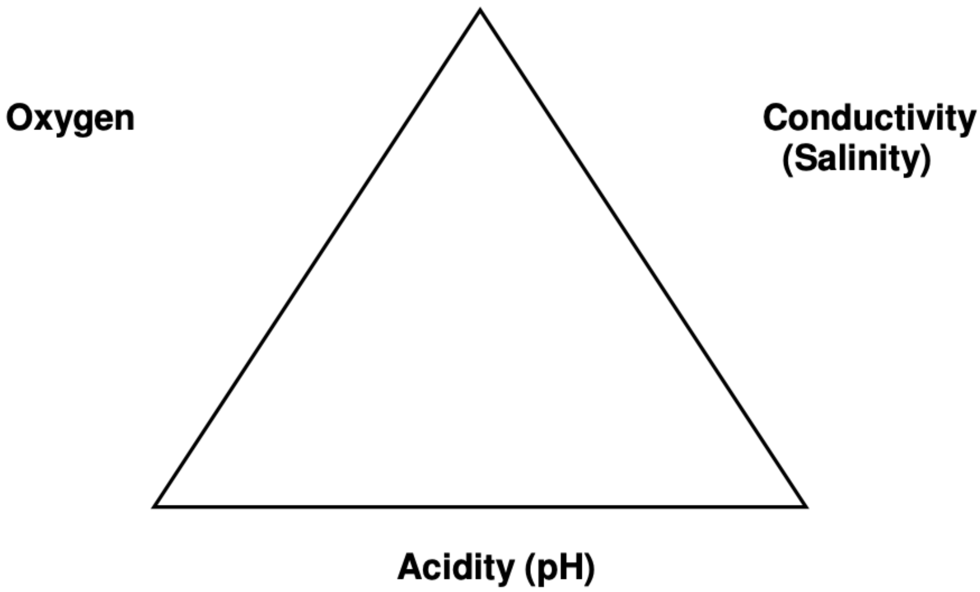
Clearly you can say that corrosion and fire are similar events. Both are an oxidation process, but corrosion runs fairly slow.

Oxygen is a vital component in the process.

Fire Triangle



Corrosions Triangle



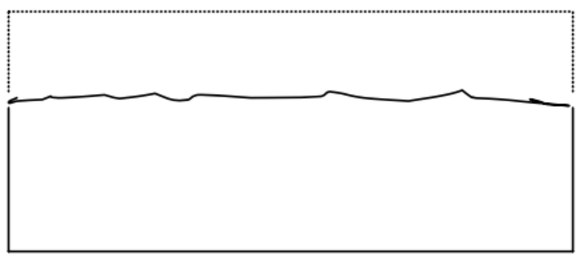
The most common oxides in heating and cooling systems are iron oxides like red rust (Fe_20_4) or black rust (Fe_30_4), also known as magnetite, which is our most common iron ore. These construction metals that are handled daily are a refined product from the metal oxides and metal oxide mixture we can find in the earth's crust. The natural status for metals is oxide and this concludes an aspiration to make the metal return into its natural state as an oxide.

In the water treatment systems corrosion comes in different shapes. The most obvious form of corrosion are:

- **Common corrosion**
- **Galvanic corrosion**
- **Erosion corrosion**
- **Cavitation depended corrosion**
- **Abrasion depended corrosion**
- **Crevice corrosion**
- **Microbiological induced corrosion**
- **Local pit corrosion or pitting**
- **Corrosion Fatigue and Stress corrosion**

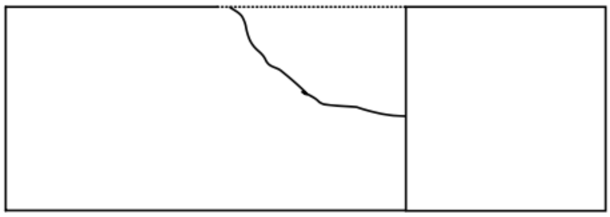
Common Corrosion

The common corrosion is, like the name says, a destructive corrosion of all the metal area.



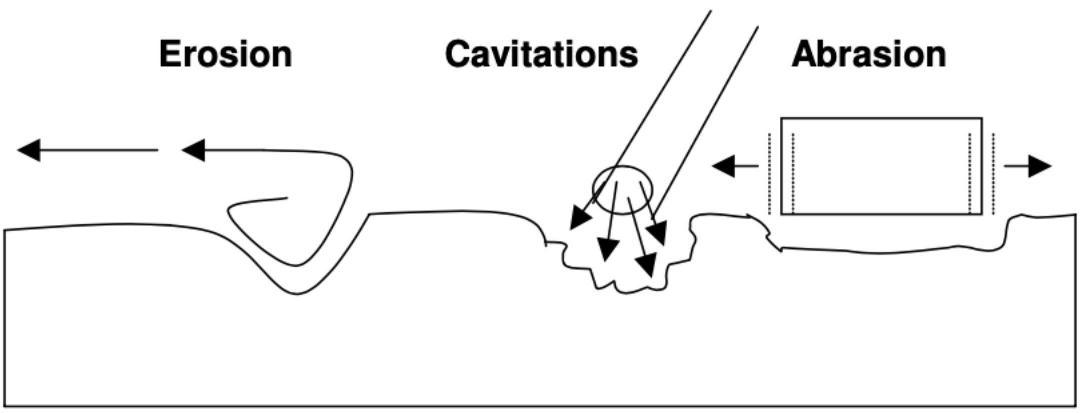
Galvanic Corrosion

Galvanic corrosion comes into existence where two metals with different characteristics are bound with each other in a water solution, which has the ability to act as a battery liquid. The ignoble metal will then become an anode and break down, just as the noble will be protected. This is the case when zinc anodes are built on the ships body to protect body and propellers.



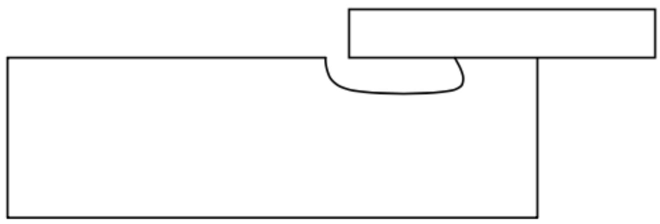
Erosion, Cavitations, Abrasion

Erosion, Cavitations and Abrasion corrosion is a grinding form which comes from either high water speed, moving parts and/or because the water contains particles of some sort, like sand, welding slag or corrosion products. The protecting oxide layer shaped on the metal gets grinded and the pure metal will be exposed, and then new oxides are shaped and will be grinded as well. The amount of grinding particles is then increased in the liquid and the process accelerates.



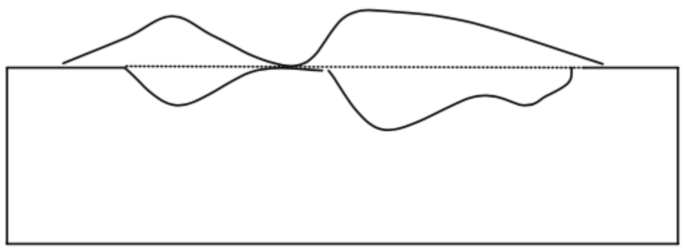
Crevice Corrosion

Crevice corrosion appears when liquids get stagnant in a small area or in a crevice between two components. The liquid in this area is changing, for example when chloride and oxygen increases. This means that the liquid outside the crevice with its different composition becomes cathode and an electrochemical cell is created (so-called concentration cell). As soon as such a cell is created its activity will increase depending on the oxygen level and with rising acid level and increased conductivity in the crevice, the liquid in the crevice will become aggressive towards metals.



Microbiological Induced Corrosion

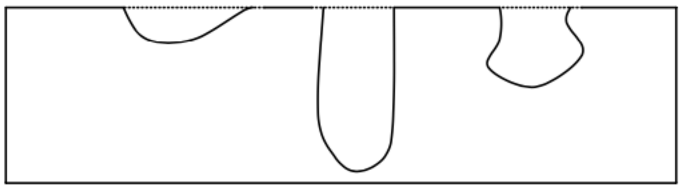
Microbiological induced corrosion appears because of algae, bacteria and other biological activity. These will affect the metal through giving it stagnant products like slime, which will make a layer or a direct attack on the metal (for example iron reducing bacteria). Even direct growth on the layer will attack the metal because of the concentration cell that is created.
Microbiological corrosion is the cause of many breakdowns and deteriorated efficiency, often due to the fact that the maintenance staff are not always aware of what is happening.



Pitting (Pit Corrosion)

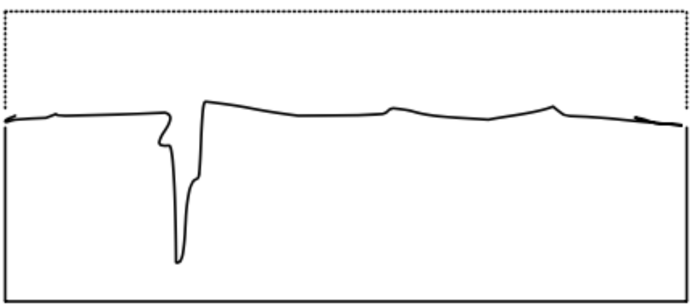
Pit corrosion or pitting is the most deceitful corrosion process. It comes punctually on small areas in a water system without the real assumption for corrosion. Small anodic areas emerge or are created on metal surfaces and an aggressive local attack towards the metal starts. The initiating of the anodic areas is often dependent on a corrosion product or other filth in the liquid to lie as a lid on the metal surface. Under this lid a process is beginning which is similar to crevice corrosion and a galvanic cell is created.

Corrosion like this comes with a speed of some tenth of a millimetre per year (in some cases this can be millimetres per year rather then tenths of millimetre). And since the material in a water treatment system is only 1-3 millimetres thick the lifetime of a system is decreased from 40-50 years to 5-10 years.
Example of heavy attacks has resulted in a system break down in less then 18 month.



Corrosion Fatigue

Fatigue is a common cause of unexpected cracking similar to stress corrosion cracking, Both these are depended on vibrating of the pipes, the risk is increasing if other kinds of corrosion appears in the system.



Change of water quality

Change of water quality is an important factor for maintain a corrosion attack:

- **Salt content**
- **Oxygen volume**
- **Speed of flow**
- **PH**
- **Contamination**
- **Temperature**
- **Added chemicals**

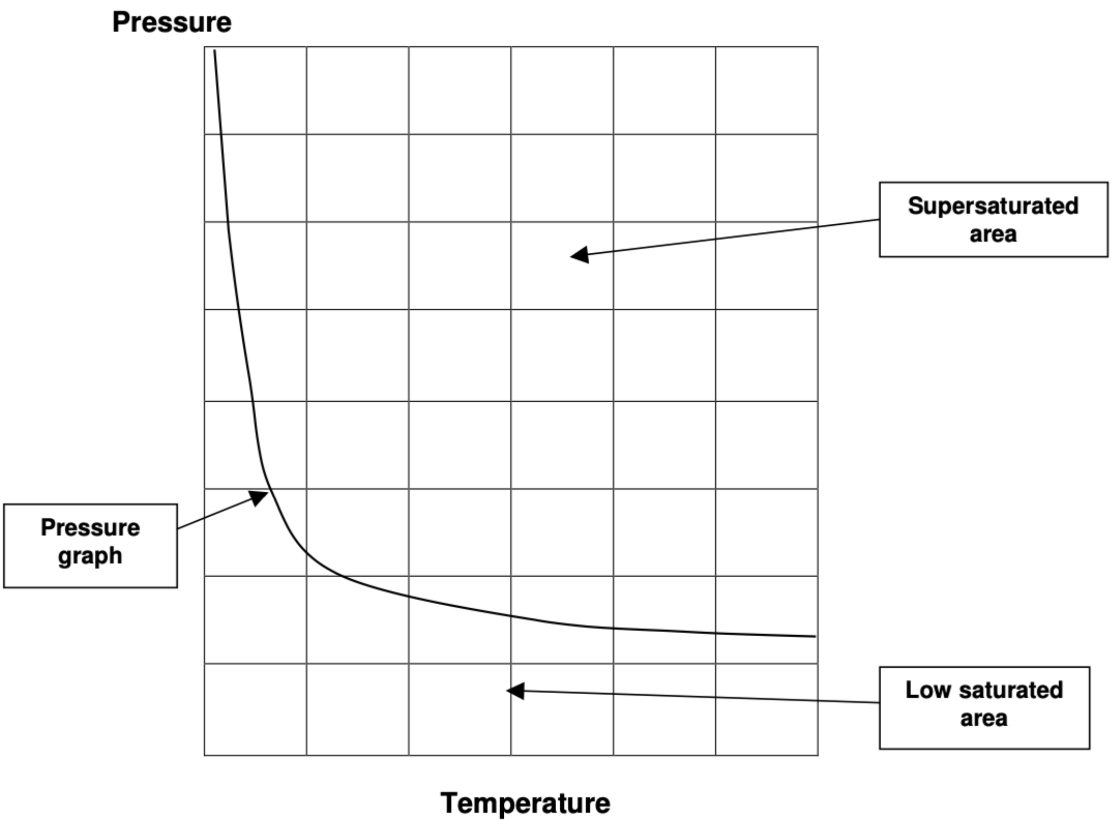
The water quality is very important in regard to corrosion.
At first corrosion depends on the amount of dissolved substance, gases within liquid, alkalinity, acidity (pH), temperature, conductivity, particle substance and organically growth (bacteria, algae).

Oxygen is always a component in an oxide formation. Oxygen released in water is the biggest cause of corrosion. The first oxide formation on the metal surface is a protection because of that the higher resistibility towards attacks on the pure metal.

A completely oxygen free environment can be more harmful then an environment where the oxygen allows some oxide formation.

Oxygen is always a part of the electrochemical reaction between water and metals, and the corrosion speed can be related to oxygen level in the water.
The most important factors for oxygen's solubility in water is pressure and temperature. Pre-pressured water and decreased temperature increases the ability for the water to combine the oxygen (Henrys law).
In closed pressured heating systems, the gas will be forced from the water because of the temperature rise and become bubbles on high stands in the system. These must be exhausted manually to prevent corrosion. A corrosion attack develops in the water line between the gas bubble and the water.
If exhaustion is not made will the oxygen that has not become metal oxide once again be solved in the water in a temperature reduction.

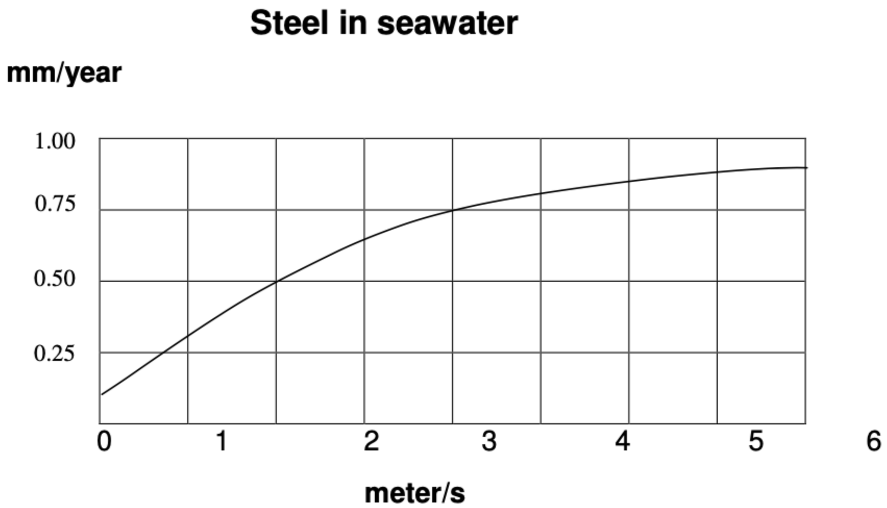
Water’s ability to combine gas.



Water’s ability to solve gas depends on temperature and pressure.
In the supersaturated area is the gas both dissolved as liquid and as bubbles.
This is the area where exhausting is to be made.

Heat and heat transfer medium which contains gas exposes themselves to pressure and temperature variations, and that leads to make the gas dissolving out and gives effect on liquid flow and the heat transfer.
Isolated bubble film creates on heat exchanging surfaces (fouling), and the problem increases with the bearing pressure on the transmission of energy.

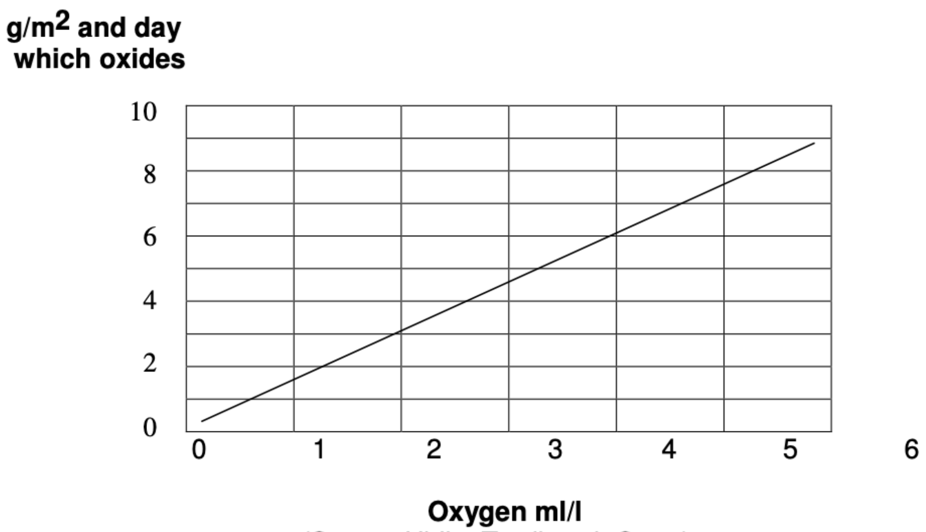
Water-speeds influence on corrosion



(Source Corrosion Handbook)

Oxygen gas contents influence on corrosion

Soft steel in slowly flowing water containing 165 ppm $CaCl_2$



(Source Uhlin, Tradis och Stern)

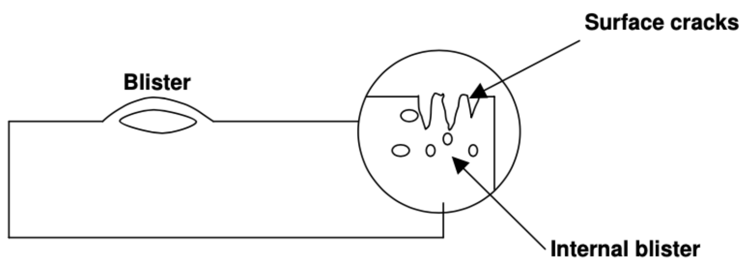
Oxygen that is used in an oxidation process creates a drift force so new oxygen can replace the used sum, all according to nature's way to compensate. In this case, between the surrounding which is rich of oxygen and the deficient environment inside a tube system.

The exchange is depending on the systems density against penetrations of gas molecules, how well the pipeline is done and if there are any internal details which can work as an osmotic membrane and let the gas through but not let any liquid pass. This is an effect, which can be shown with plastics for example. Older floor heating systems with plastic hose are known to have this effect. Nowadays the factories say they have a hose with oxygen sealed layer.

Most of the oxygen occurring in the water treatment systems today has come through dilution water when they are newly built, or at repairs or exchanging components, with permanent tap and refilling of the liquids.
Other gas and substances, which occur and can be dangerous, are hydrogen gas (H_2), carbon dioxide (CO_2) and. hydrogen sulphide (H_2S).
Hydrogen gas is a gas formed at a corrosion process. Water contains one oxygen atom and. two hydrogen atoms (H_2O), which breaks up in a galvanic process.

The oxygen part participates in the corrosion process while the hydrogen gives an acidity effect through increasing the amount of free hydrogen ions (lower pH). Except that the liquid in this way supports and increases the corrosion process, exhaustions corrosion is created when the small hydrogen atoms penetrates in to the metal and creates blisters with the consequence of deterioration on the validity.

Hydrogen gas induced corrosion



Carbon dioxide is a gas created from combustion, vegetable synthesis, fermentation processes and so on and combines it self to lime bearing material. It dissolves easily in water and creates under pressure together with water carbon acid (H_2CO_3). Carbon acid is a weak acid with a pH-decreasing effect (souring) and dissolves on lime bearing material. In pressurised technical water treatment system large amounts of carbon dioxide resolve itself as a carbon acid, some parts considered normal carbon acid, and surplus is considered as aggressive and attacking metal.
A lot of the natural mineral waters contains carbon acid taken from the ground while passing through. Soda and beer contains pressurised carbon acid or it has been created during the fermentation process. If the capsule is removed from one of this kind of bottle the carbon acid will split up into its components, carbon dioxide and water, since carbon acid usually can't exist as a liquid in atmospheric pressure. Increased temperature decreases the solution in water.
Because of its ability to create a liquid together with water, the half-life for carbon dioxide attached to water fairly long (approx. 10 hours), which makes the gas hard to get out of the system.

Hydrogen sulphide in the technical water treatment systems is often created through a breakdown of organic material (bacteria, algae and so on). It's the albuminoidal substance in the organic material that reacts with the surrounding and creates the hydrogen sulphide.
It's a substance that is very aggressive towards metal and it has a characteristic smell (rotten egg). In the modern cooling systems with glycols mixed water the glycol can become a nutrient solution for organic material, which has gained access to the system.
This often happens through a lack of maintenance and servicing on the mixing vessel for filling of dilution waters mixture. A part of the mixture remains in the vessel and. is exposed to a breakdown between oxygen and organic material. This is mixed with new liquid and toxic residue in the system when filling and a corrosion attack can start.

To prevent breakdowns in the system there are some measures to be taken.

When a new construction is done, the materials must be chosen with the consideration that galvanic elements don't appear. The material that is chosen cannot be too far from each other in the galvanic series.

Control that chosen material doesn't cause an osmotic effect.

Work shall be done so the greatest possible tightness is sustained, for example rather to make a welded pipe joint then strap the tap with flax or some other similar gasket.

Chose the pipe dimensions and components so that the liquid speed does not cause erosion corrosion or cavitation.

Flush the systems properly, eventually section by section, squeeze the system water out with the help of nitrogen gas. This means that the remaining gases will stay but not cause any problems to metal. To make solid water you need a degassing unit.

Fill the system with a liquid that is degassed, filtrated and mixed with the correct propositions anti-freeze where it should be.

Plan the work so that the tapping and refilling takes place so seldom as possibly during the building time.

Make sure that there is a degassing and purification unit connected during starting and running the system.

Control the oxygen limit during the operating duty.

Send water samples to a laboratory, to control the sum of pollution in the water. This gives a value that will be compared in later samples to establish which metals and substance and in what amount they dissolve themselves in water.

In existing systems the corrosions process may already have started, and the maintenances is often based on the knowledge about many different ways to with the lowest cost achieve or maintain maximal operating economy and life length on the systems. Then problem occur this start to go more into hope and expectations then knowledge through control and follow-up on the system. Then when problems and breakdowns are starting to get to heavy it's easy to choose the cheapest, quickest and easiest way out of the problems.
If the decision-maker don't have the proper knowledge about the backgrounds of the problems it's most likely the problems will get worse.

Just about 100% of the problems that are shown in technical water treatment systems can be related to the most important component in the system, the energy transferring media, commonly water or chemical solutions with water as base.

Chemical solutions are often used to lower the freezing point on the liquid and/or prevent corrosion (so called inhibitor) on the systems component.
Adding mixtures to pure water will only decrease the waters energy transferring quality, a disadvantage which as to be accepted to obtain the new qualities you try to create with the added mixture.

One more disadvantage is that the added mixture creates a requirement of control. The chemical substance is not solid and through wrongful handling or in wrong surroundings it can give the opposite effect that it was meant to do, through destruction or creating of new substance.
If this is the case and how long the process has gone, all this can be established with a measure from a water sample.
With this as basis right measure can be done.

Corrosion damage

- **Total breakdown**
- **Heavy material decreasing**
- **High frequency of leaking through pitting and cracking**

Primary corrosion causes

- **Common corrosion**
- **Galvanic corrosion**
- **Decay**
- **De-alloy**
- **Deposit attack**
- **Pit corrosion (Pitting)**
- **Crevice corrosion**
- **Erosion corrosion**
- **Stress corrosion**
- **Fatigue corrosion**
- **Abrasion corrosion**

Secondary corrosion causes

Unproposed contribution or man-made courses from:

- **Manufacture**
- **Contractor**
- **Consult**
- **User**
- **Maintains and service personal**
- **Affection from support system**
- **Galvanic affect from electrical system**
- **Magnetic affect from electrical system**

Corrosion is a complex process, its highly important that the maintenance staff is educated so they recognize these problems before it goes to a complete breakdown in the system.