FORMS OF CORROSION

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FORMS OF CORROSION

In practical terms, the salient features of the system and water being considered will dictate the forms in which corrosion may manifest itself. A discussion of the basic mechanism of these forms of corrosion is quite useful in gaining a more complete understanding of the process of corrosion.

The following describes the cause and characteristics of some common corrosion mechanisms affecting water-bearing equipment. Some are related to the design of the system, others to the composition of the water phase and still others to the peculiarities of a particular metal. While it would be virtually impossible to cover every corrosion mechanism known today, the general information contained should be adequate for normal applications.

UNIFORM ATTACK (GENERAL CORROSION)

General corrosion occurs when many anodic shells are combined to few cathodes. The overall potential is controlled from the total potential of the cathodes.

If all corrosion manifested itself as an even, uniform attack over the entire metal surface, the length of service and special design considerations could easily be determined in advance and equipment could be safely designed for the intended "lifespan".

Unfortunately, this is not the case. Most corrosion problems constitute localized attack at susceptible metal areas. It is more difficult to make predictions relating to design and service life under these conditions.

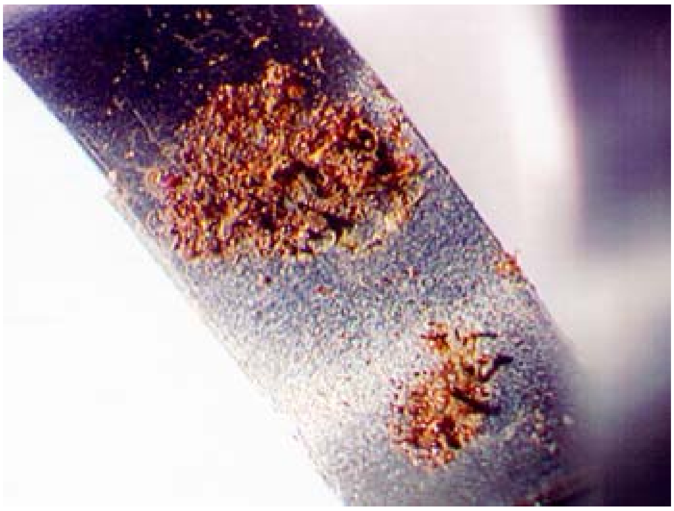
PITTING

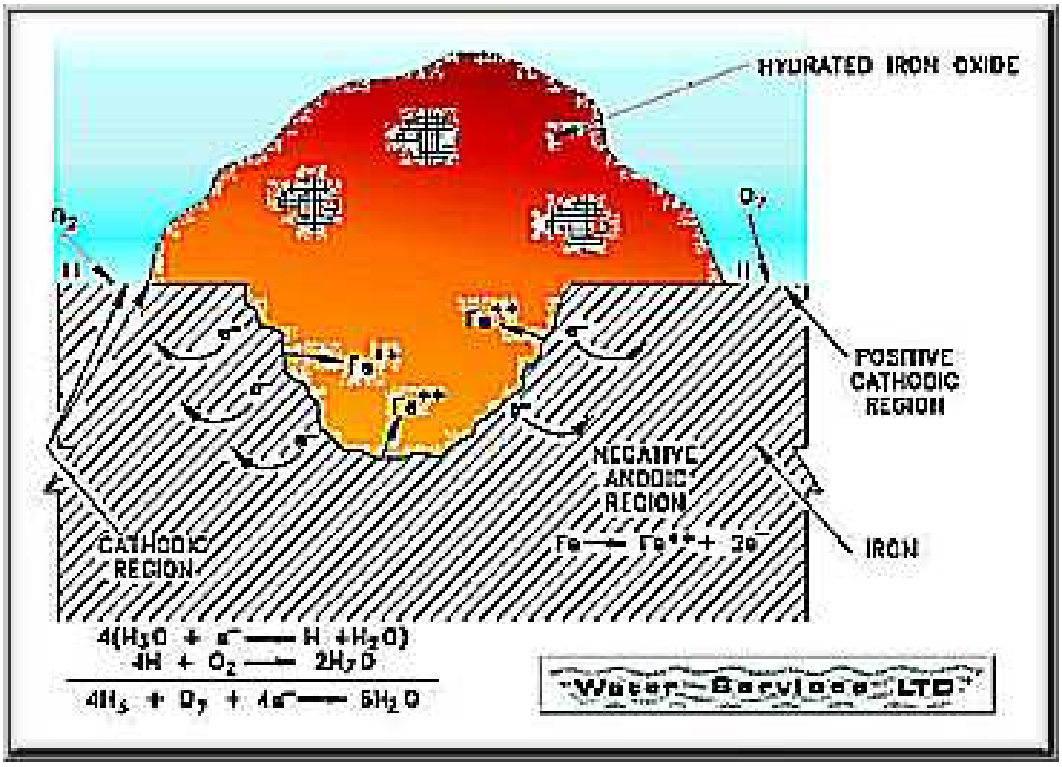
Pitting is a type of localized attack commonly found in water-bearing equipment, and is caused by the formation of highly active, local anodic sites. These may result from unequal ionic concentrations or oxygen differentials. The sites may be found at high temperature zones, at points of metallurgical defects or at cuts, scratches or crevices on the metal surface.

The primary consideration is that pitting is the most common cause of metal failure. One perforation may damage a critical heat exchanger sufficiently to disrupt an entire plant process.

The depth of the pit is in direct proportion to the ratio of the large cathodic area to the small active anodic site. The seriousness of a pitting problem is often expressed in terms of a parameter called the "pitting factor"; the ratio of the pit depth to the average metal penetration.

Average metal penetration is often measured by recording the weight loss of corrosion test specimens over a period of time. Corrosion rates can then be expressed as mils per year (mpy). The higher the ratio of pit depth (in mils) to corrosion rate (mpy), the more serious the localized corrosion and the greater the danger of metal failure.





DIFFERENTIAL AERATION CELLS

Pits are often covered by an outer coating of corrosion products; in ferrous materials these are called tubercules, barnacles or carbuncles.

The underside of the tubercule may be composed of ferrous hydroxide in which case progressive oxidation will cause a brown hydrated ferric oxide covering to form. The area between the pit and the body of the tubercule is oxygen deficient, with increased concentrations of chloride and sulfate ions.

The water above the deposit contains dissolved oxygen, but the area below the deposit is oxygen deficient. A differential aeration cell is therefore formed with the oxygen deficient area becoming the anode. The result is extensive corrosion and an unacceptably high metal loss rate.

A self-perpetuating corrosion cycle is established. The metal lost through corrosion forms additional deposits which in turn create new differential aeration cells, and result in more corrosion.

Frequently, the cycle induces rapid failure, despite the presence of a corrosion inhibitor. The metal surrounding a deposit will be cathodic to areas beneath it because they may be protected by an inhibitor film. A small anode is, therefore, developed within a relatively large cathodic area.

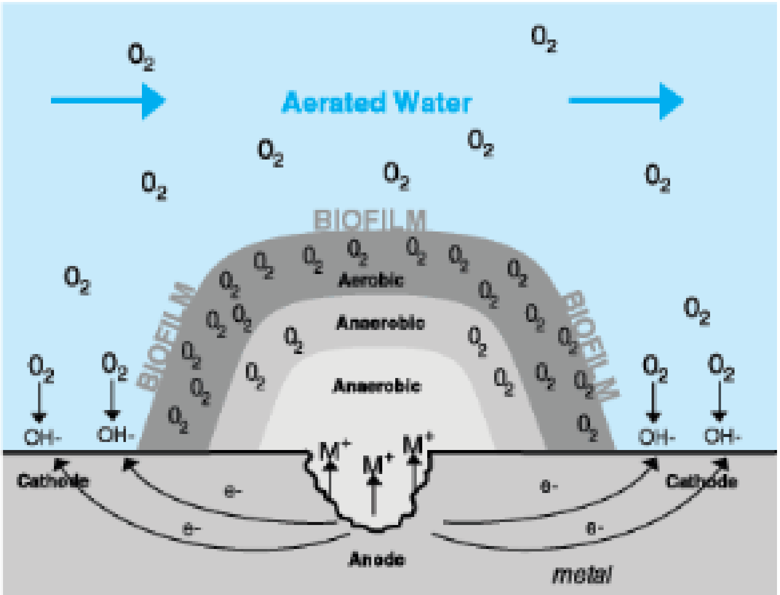
The damage potential of this relative area effect was described in the section on Physical Factors Affecting Corrosion. In this situation, rapid corrosion ensues, with complete metal perforation not uncommon. It is essential to maintain a clean cooling water system to avoid costly downtime of critical process equipment.

Low-flow areas are particularly susceptible to this form of corrosion. Suspended .materials settle in these areas, causing extensive deposition and subsequent attack. This problem is magnified along heat exchange surfaces when deposition causes unequal heat transfer, which results in temperature differentials, and the creation of a corrosion cell, with cooler areas becoming cathodic to warmer ones.

These conditions lead to rapid corrosion. The process is self-limiting in stagnant or low flow areas because the tubercule will eventually become sufficiently dense to prevent diffusion of the metallic ions into the water. However, in a cooling water system, flow rates are often sufficient to remove this potentially passivating layer of corrosion products.

Fresh metal is, therefore, continuously exposed to corrosion.

Biofilm



What Is Biofilm?

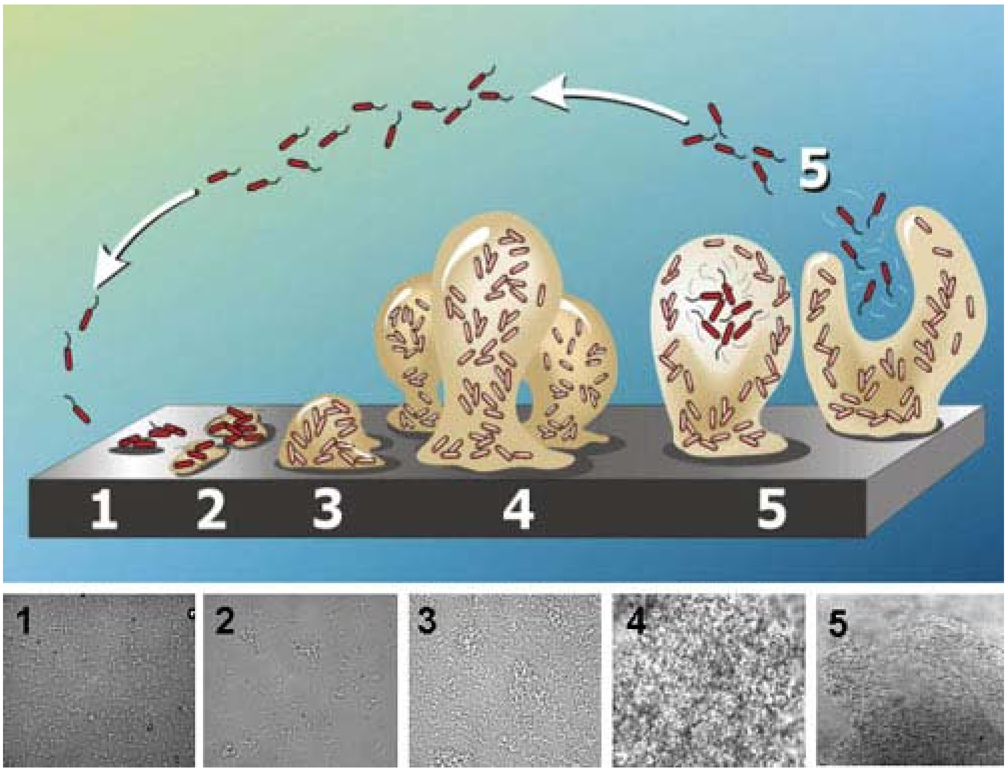
Water in the liquid phase is like a dessert for micro-organisms, with few nutrients available for growth. In addition, flowing water provides an unstable environment in which to live. Consequently, in an effort to maintain their viability, miroorganisms seek solid surfaces conditioned with nutrients sufficient for growth. When attracted to a surface, micro-organisms deposit, attach and initiate growth. As they grow and multiply, newly formed cells attach to each other as well as the surface, by creating a 'polymer matrix', or slime.

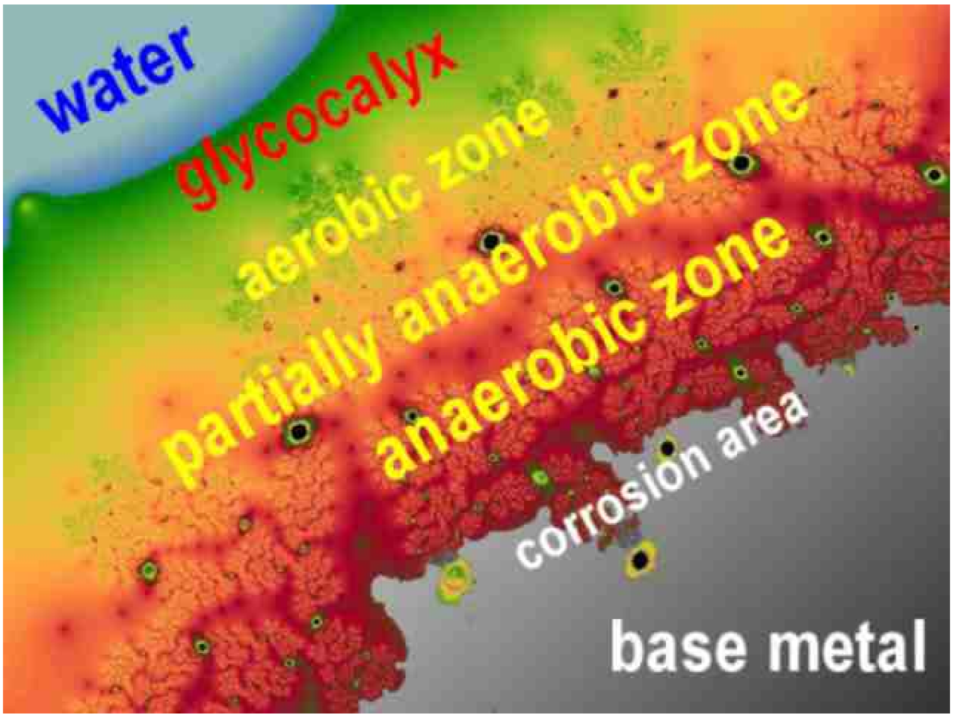
In man-made water systems, this deposition and growth results in a slime layer, or biofilm, on surfaces in contact with water, but particularly at or near heat exchange surfaces where the temperature is right for growth, and where there is a sufficient nutrient source from scale, sediment, corrosion products, and trapped organic and inorganic molecules supplied by the flowing water.

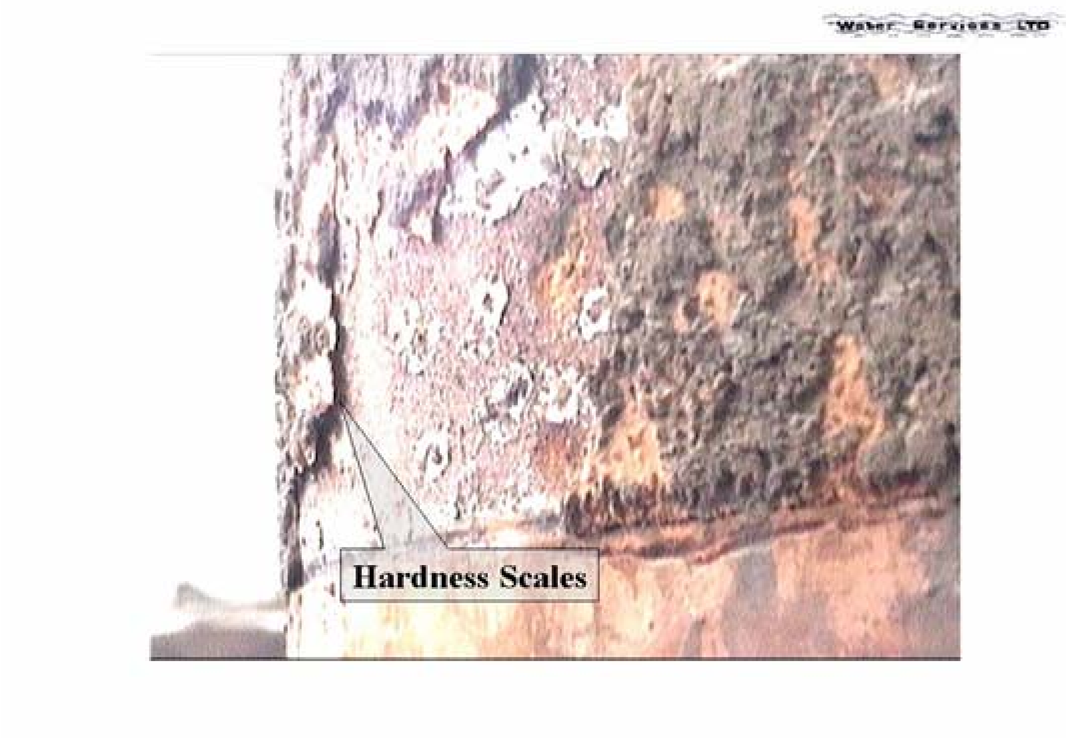
In general terms, the dominant population will consist of aerobic (requiring oxygen), and anaerobic (living without oxygen) bacteria interspersed with algae (if light is present) and fungi which in turn support predatory organisms such as protozoa and metazoa. These predatory organisms feed on the biofilm like cattle grazing a field and ingest bacterial cells for food.

Biofilm form a safe habitat for pathogenic bacteria like Legionella to live and proliferate. A link has been established between amoeba, a predatory protozoa, and high levels of Legionella in a water system. When an amoeba ingests a Legionella bacteria, unlike normal bacterial cells which are digested, the Legionella organism colonises the amoeba and proliferates within it until the expansion in numbers cannot be contained. This results in the amoeba bursting and releasing huge numbers of Legionella in a concentrated pack into the water. This can then be transported to outlets, disseminated in a aerosol, and if inhaled can lead to Legionnaire's Disease.

It therefore follows that the key to maintaining the quality of water being stored and transported through a man-made water system is to control the development of biofilm within that system.



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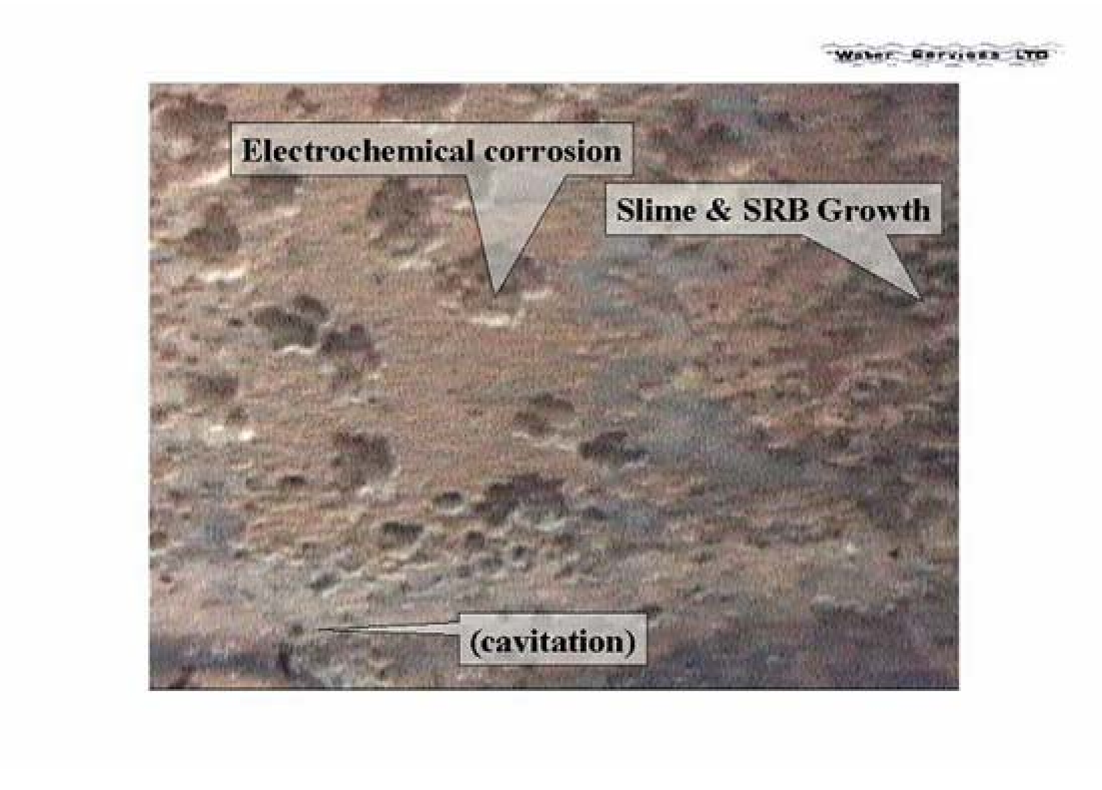
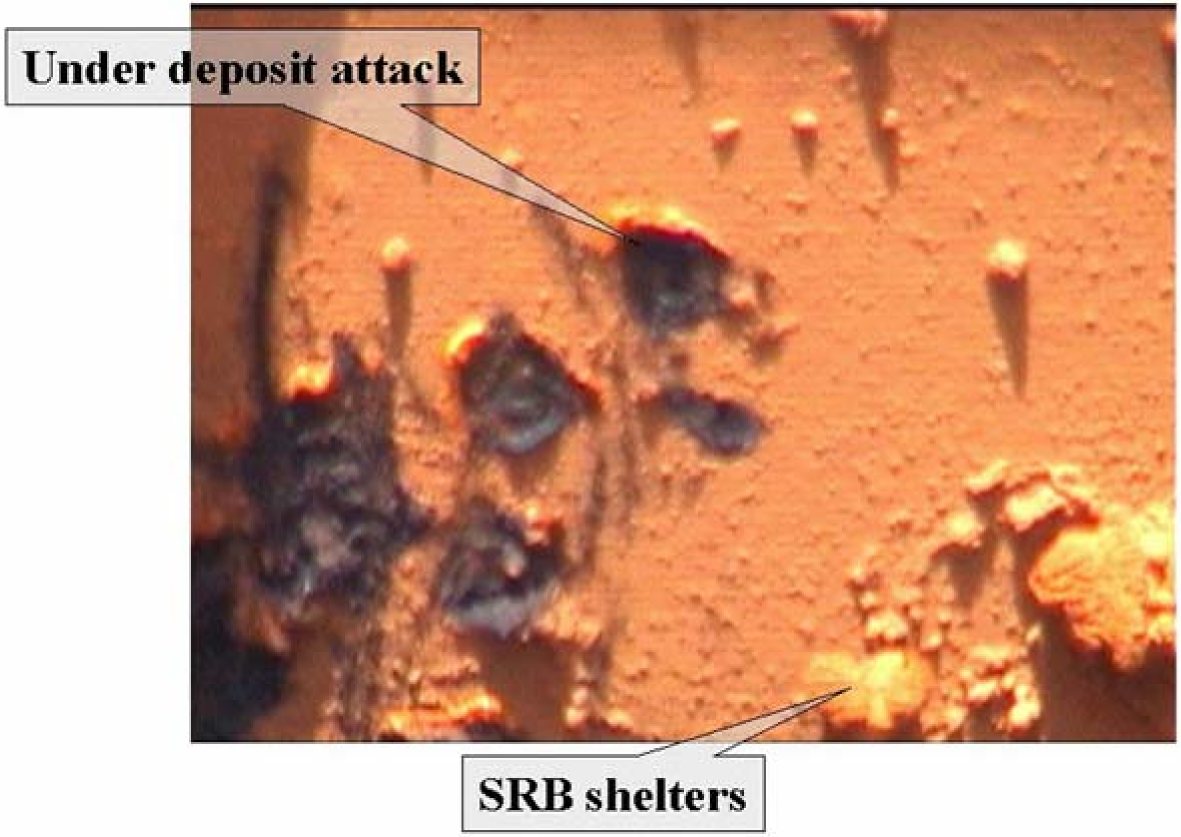
Hardness Scales


Water Services LTD
Electrochemical corrosion
Slime & SRB Growth
(cavitation)



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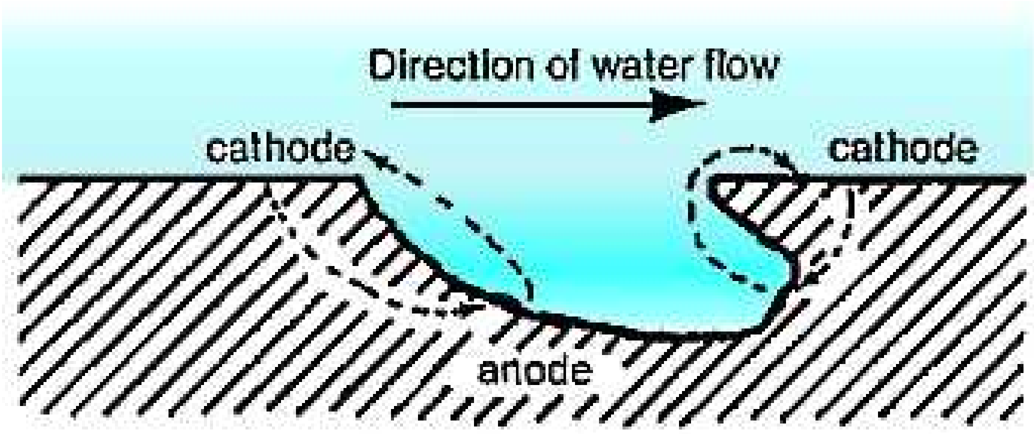
EROSION

This form of corrosion is a class of attack associated with high velocity, and consists of two sub-classes, impingement and cavitation.



Cross-section of an impingement pit

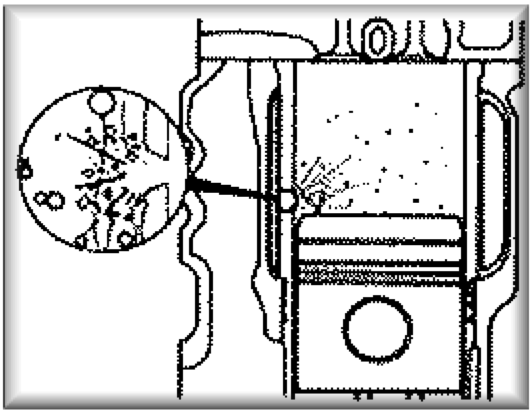
Vibration Corrosion (Cavitation).

Vibration Corrosion (Cavitation) is a very usual type of deterioration in heavy duty Diesel Engines. It is potentially the worst of all cooling system problems for diesel engines is cylinder wall pitting, or cavitation erosion.

Cavitation occurs in high velocity, variable pressure situations and in waters containing dissolved or entrained gas. Pockets of vapor form at low-pressure regions, and as the water flows to zones of higher pressure, the pockets collapse (implode), causing shock pressures as great as several thousand psig. These high shock pressures physically destroy protective oxide films and dislodge metal grains from the surface.

The evidence of cavitation is often deep, circular pits, without tuberculation. The attack occurs in many areas, including the suction side of pump impellers, sharp bends in piping systems and the discharge side of globe or gate valves. It may also occur in diesel engines, caused by the pressures created by piston slaps. High dissolved nitrogen concentrations have been found to aggravate the condition. The use of a suitable film-forming corrosion inhibitor can aid significantly in retarding the attack.

Cavitation is the result of air or steam bubbles violently imploding onto the surface of the cylinder. This happens as the cylinder fires, causing the cylinder wall to vibrate. The cylinder first pushes the coolant back and then actually moves away from the coolant as it returns to its original position, causing a vacuum pocket to form. This vacuum pocket then implodes against the wall of the cylinder with surface pressures up to 60,000 psi.



Pitted Cylinder Liners Constant vibration of the cylinder liner causes a momentary vacuum to form on its surface. Coolant boils into the vacuum and vapor bubbles implode on the surfaces of the liner, digging into unprotected liners. Cause pits which can extend over time, through the thickness of the liner and allow coolant to enter the combustion chamber or crankcase.

Diesel requires a much higher compression to detonate (explode). This higher detonation means much higher pressures on the engine.

That's what makes a diesel so loud. In all engines (gas or diesel),The piston hammers against the side of the cylinder wall while transferring up and down motion to the rotating crankshaft. In a diesel it has a much harder impact. Imagine hitting a bucket of water with a hammer. What this does is cause the cylinder wall to first move towards the coolant, and then away from it, at a very high frequency. This rapid movement causes very small vapor bubbles to form.

These tiny bubbles then implode or collapse as the wall comes back again. This creates very high pressures in very tiny areas. This is what causes small horizontal holes to form. These holes will eventually drill right thru into the combustion chamber. This will allow coolant into the oil when the engine is off, and oil into the coolant when running. This can happen in as little as 500 hours of operation when using just water as a coolant.

Cavitation of the cylinder wall begins when air bubbles remove the wall's protective oxide film. Flexing of the cylinder wall after the fuel mixture explodes in the combustion chamber causes cylinder wall vibration and creates air bubbles in the coolant. Concentration of air bubbles increases when cooling system pressure is low or when the system leaks. Also, increased vibration amplifies the quantity of air bubbles. Vibration multiplies when the engine is run cold, because of increased piston-to-cylinder clearance. Vibration also multiplies when the engine is lugged.

These air bubbles form on the outside of the cylinder wall (perpendicular to the wrist pin) and then explode inward, or implode. When air bubbles continue to implode, sufficient energy is released to physically attack the cylinder wall and remove the oxide film. Furthermore, vibration inside the block, particularly around wet cylinder liners, causes tiny pockets of reduced pressure, where heated coolant vaporizes, forming bubbles of steam.

As these bubbles collapse against internal surfaces they physically erode the metal. This “cavitation erosion” can eat inholes right through liners and cooling jacket walls, al-lowing coolant into the cylinder.Corrosion and pitting then take place at a high rate.

Eventually, a pit can become deep enough to break through the cylinder wall and allow coolant to leak into the cylinder. This coolant leak contaminates the lubricating oil. Supplemental coolant additives coat metal surfaces and control cavitation-erosion and pitting.

Unfortunately, small particles or ferrous scale often shield the surfaces underneath from the protective action of coolant additives. If this condition persists, pits can form. Keeping your cooling system clean, along with regularly replenishing your coolant additives, helps prevent pitting. However, if coolant additives are not added at the proper intervals and in correct quantities, cavitation erosion and pitting intensifies. Eventually, coolant can penetrate the cylinder wall and cause major damage to the engine.

Our products WSC 8140 and WSC 8170 DP have been designed to protects liners from cavitation. They are contributing a thin elastic protection film, which absorbs imploding and protects liner from high imploding pressures.

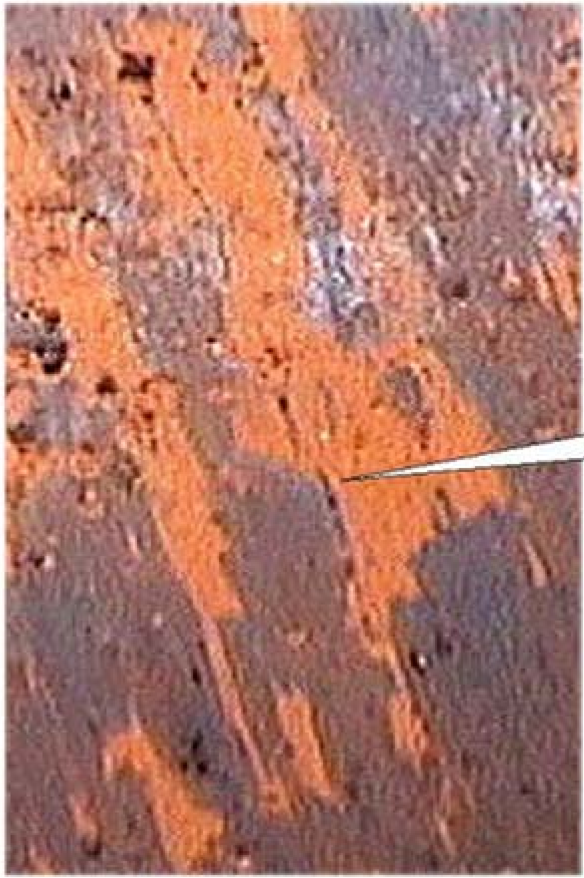
They also (especially WSC 8170 DP) modifying the surface tension of the water, accelerating the vibration return, which is leading to lower implode pressures.

CRACKING

There are two general forms of cracking corrosion, both associated with the configuration of the crack. These are intergranular cracking, which occurs between grain boundaries and transgranular cracking, which takes place across a grain boundary. Intergranular cracks usually occur at anodic grain boundaries. Stress corrosion cracking of austenitic and martensitic stainless steels provides an example of one such attack.

During manufacture, a metal is often left in a stressed state; it can crack perpendicular to the direction of the stress. The attack is aided by high temperatures, the presence of high chloride concentrations, or other corrosive conditions. Proper manufacturing procedures can minimize the problem by heat treatment to remove residual stresses.

The presence of crevices should be eliminated. Transgranular cracking occurs under cyclical stress conditions (corrosion fatigue); pure metals are more resistant to this form of cracking.



Crack created between the cavitation pits