CHEMISTRY

$7 Billion Rust Spot

Every year a fortune is lost to corrosion, deadly enemy of home equipment and of the massive, complex machinery of the nation's industry. Here is what can be done about it.

By MICHAEL J. WALKER

➤ CORROSION to most of us means a rusted out tail pipe on the family car, a useless garden tool or a failure in the plumbing. But the same enemy costs us about $7 billion a year by eating away at the nation's industrial plant.

Corrosion spoils much of the goods produced by industry, and even worse, gnaws away at vital production processes and equipment.

It's like cancer, afflicting all companies. It spoils products, forces plant shutdowns, wastes natural resources, causes losses of efficiency, drives up maintenance and packaging costs. Companies also suffer from loss of fuel and water, spoiled food, lessened electric power, and disrupted transportation.

Last but by no means least are the deaths and injuries experienced by plant workers because corrosion weakens vital industrial structures and causes accidents or explosions.

Petroleum, gas, chemical and shipping companies, with their broad array of boilers, tanks, ships and pipelines probably suffer most of the damage because of the corrosion that takes place in liquids.

Railroad, electronic and power companies, however, and virtually every other type of company, also suffer because corrosion also takes place in humid atmospheres and underground.

Prior to 1900 industry was virtually powerless to combat corrosion because engineers knew little about the process and its causes and had few, if any, effective inhibitors to work with.

Davy in 1825 in England scientificially described a form of corrosion caused by salt water on copper plates of ships and even prescribed an inhibitor that worked. But, as has too often happened in the past, a major scientific discovery was taken too lightly and forgotten.

Saltwater Corrosion

Today salt water is contributing to corrosion, although in a different way. The drought has lowered many of the nation's rivers to the point where seawater is pushing up their mouths and corroding machinery along banks.

After steel production had zoomed and industry had made widespread use of this metal around 1900, however, firms encountered a staggering loss and cost problem, and engineers turned to scientists for help. Private firms, institutes, universities and even the Government then sponsored large-scale programs of research. Their aim: to understand the nature of corrosion and the precise factors that promote it, and to devise an arsenal of weapons which engineers could use to wage war against the enemy.

Looking for specific things in the environment that promote the destructive process, scientists discovered that in liquids and underground it is primarily the amount of free oxygen present that governs the rate, but such things as sulfuric and other acids, salt, alkalies and rising temperature also actively promote attack. Pure water without free oxygen corrodes very little. Also hard water—that is, water that contains calcium carbonate—corrodes less than soft water.

In the atmosphere, scientists discovered, it is the amount of humidity that governs. Desert areas with no humidity experience virtually no atmospheric attack. Sulfur compounds, emanating from the burning of coal as fuel, are given off to the atmosphere and also promote atmospheric attack, so atmospheric corrosion around industrial areas is greater. Sea coasts also experience heavy atmospheric attack because of salt spray.

Iron and steel are the metals suffering greatest attack from this enemy, especially on uneven surfaces or in crevices, but scientists discovered that all metals are susceptible. In their highly refined state, metals have a tendency to revert to their ores or to combine with such things as oxygen into compounds of less energy.

The less susceptible metals like aluminum corrode, but as this attack progresses an adherent film or layer deposits on the surface of the metal and inhibits further attack.

For a time there was controversy over several theories that were proposed to account for the process. Eventually, however, it was the so-called electrochemical theory of attack that won recognition by corrosion scientists.

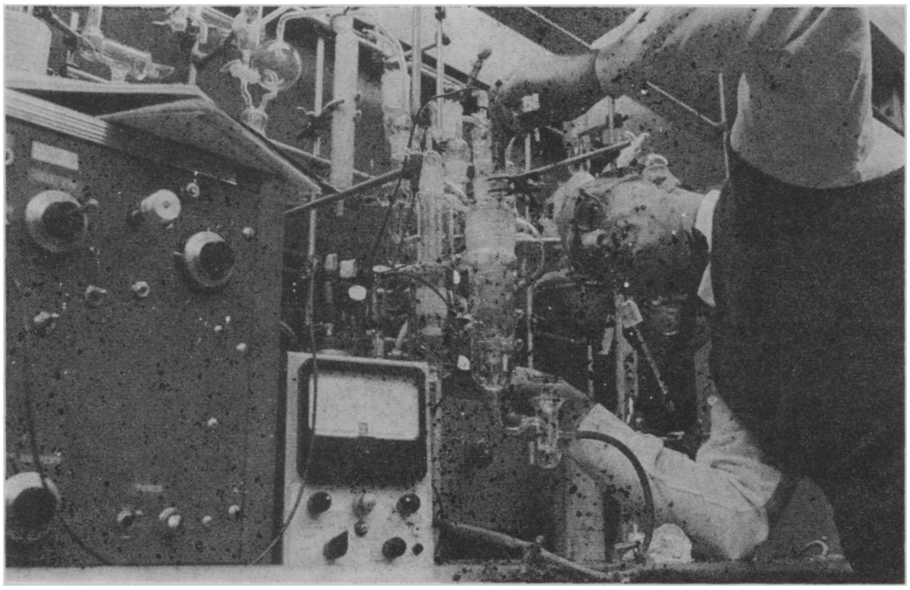
This theory, however, merely accounts for wet-corrosion of metals and is not intended to explain the corrosion resulting from gaseous attack (hydrogen is known to cause corrosion) and the chemical attack experienced by such nonmetals as concrete.

Electrochemical Theory

According to the electrochemical theory, corrosion is like the process taking place in flashlight batteries. Within a metal plate, many positive and negative poles are naturally set up, called cathodes and anodes. If a liquid environment is present, it short-circuits across these poles, enabling a current to flow as it flows through a battery when you turn the switch on.

As the current flows, charged atomic particles known as ions leave the metal at the positive (anode) pole and migrate into the liquid. Where they leave the metal, corrosion occurs, often leaving a depression or hole in the metal.

Metals are more likely to form such cells if they contain impurities, but the environment short-circuiting the poles must have such things as oxygen, sulfur or salt present or the current will not flow. Break this circuit, scientists reasoned, and you can slow down the attack.



DuPont

CUTTING CORROSION COSTS—In an effort to cut the staggering costs of corrosion in chemical equipment, this scientist tests a DuPont process that coats the insides of pipes, flasks and other apparatus with an oxide film that lessens the effects of corrosion-causing electrical currents.

What makes it so difficult, however, is that there are many kinds of corrosion, depending on the materials used and conditions present.

For example, the so-called galvanic form of attack occurs when dissimilar metals are linked together and then are subjected to a humid, corrosive environment. The corrosion takes place at the juncture of the two metals.

On the other hand, the entire area of a metal exposed to corrosive environment can be attacked, examples of which are rust and tarnish. Pitting is a localized form of attack where the pock-mark or tiny pit forms and weakens areas of tanks or vessels or pipes.

Stress corrosion is the attack occuring at riveted junctions or at welded junctions and causes a vessel to crack or even collapse under normal stresses in corrosive environments. Dezincification is a form of attack in which zinc is corroded out of an alloy.

Science Attacks

After years of studying these and many other types of attack, corrosion scientists were able to devise weapons for the engineer. From these the engineer chooses one that will most likely solve his particular corrosion problem. Most of the methods work because they break the tiny circuits and prevent current from flowing.

One weapon is the use of protective coatings and linings, such as paints, plastics, coal tars, glass, porcelain, ceramics, chromium, silver, tin or lead. These materials are coated on equipment as it is built, enabling the equipment to withstand attack after the equipment is put to work in an aqueous or humid environment.

Over 50 resistant metals and alloys have been identified by corrosion scientists, and these constitute a second weapon. These materials run the gamut from aluminum to zirconium and include such workhorse materials as monel and stainless steel. Design engineers replace equipment parts that corrode with parts made of these materials that resist attack. Thus, stainless steel, an alloy made by combining chromium with steel, stands up nicely in the kitchen in tableware and in many tools and parts in industry.

Another material coming into use is a high tensile steel with the characteristic, when left unpainted, of forming a rust coating that becomes a protective skin over the steel, developing only as a very thin layer that inhibits further rusting.

The third weapon involves the use of electrical current. A current is induced to flow to a corroding area, rendering inactive the tiny currents that generate corrosion, or current is induced to flow out of a so-called sacrificial piece of equipment, which is allowed to corrode away and then be replaced. The sacrificial piece is not an essential part of the equipment, hence corrosion does not attack vital parts.

As a forth weapon, corrosion scientists advocate the use of numerous nonmetallic, noncorrosive materials such as glass fiber-reinforced plastics for a variety of chemical and other plant applications where corrosion normally is a severe problem. For example, plastic pipe is becoming increasingly popular. Other materials available include wood, glass, ceramics, carbon and rubber.

Corrosion inhibitors constitute the fifth weapon, functioning much like some antiacids do in an upset stomach. These chemical compounds, including pyridine, phosphates, silicates, and chromates, are sprinkled into the solution and form a protective film on the metal surface to prevent corrosion from taking place.

Corrosion scientists also consider control of the environment as a weapon. Removing humidity from the air in storage areas, lowering temperature, covering the object to be protected in a cocoon (mothballing), or removing oxygen from the water.

The seventh weapon is the use of design changes in equipment. Parts that are known to corrode are designed and built heavier so they will stand up longer even though they are being attacked. Other design changes include boxing in complicated structural shapes with easy-to-paint flat plates and welding combined with heat treatment instead of riveting.

It was the discovery of this arsenal of weapons that endeared corrosion science to industry. Though engineers doubt they can eliminate corrosion completely and permanently, they now believe they can keep the enemy in check and allow industry to continue to pour out the goods needed by a growing population.

A major function performed by corrosion scientists in addition to research is education. They are educating industrial engineers to the basic nature of the corrosion process and to the arsenal of weapons available for use, and they are persuading engineers to test for corrosion as a standard procedure in industrial planning.

The major limiting factor for industrial engineers is cost. Paint, for example, is inexpensive and easy to apply and can be widely used for certain types of protection, but such materials as alloys and pure metals drive production costs up significantly. Cars made exclusively of such noncorrosive materials would be much more expensive. The industrial engineer must choose from the arsenal the inhibitor that offers good protection at little cost.

Corrosion scientists are also on a standby basis for industry, available to tackle any difficult corrosion problem that arises. For example, auto makers have become alarmed at the corrosion caused to car bodies and parts like bumpers by the salts being dumped on city streets in winter to melt snow. They have called on corrosion scientists to provide them with additional inexpensive inhibitors to diminish such corrosion.

• Science News Letter, 89:26 January 8, 1966

Do You Know?

The herbicides diuron, simazine, atrazine and prometryne must be applied when the weeds to be killed are in the *seedling* stage of growth.

Release of reservoir water is one method of keeping stream *temperatures* below levels harmful to some commercially important ocean-going fish, such as salmon.

About two percent of earth's water is locked in the *ice* of the Arctic and Antarctic.

• Science News Letter, 89:26 January 8, 1966