Chemistry

From the recent International Conference on Biologically Induced Corrosion at the National Bureau of Standards in Gaithersburg, Md.

'Bugs' and hydrogen embrittlement

Many metals lose ductility and tensile strength upon absorption of hydrogen. Known as hydrogen embrittlement, this process can lead to sudden catastrophic failure of a metal. At Harvard University, Marianne Walch and her colleagues are studying the possible role microbes play in the embrittling—and related stress corrosion cracking—of metals.

Sulfate-reducing bacteria (SRBs) are capable of producing large amounts of hydrogen sulfide (H_2S) in the thick biofilms that come to coat nearly all unprotected metal surfaces in a moist environment (see p. 42). Because sulfide ions are known to enhance the hydrogen-embrittlement process, Walch suspects microbes—like those seemingly ubiquitous SRBs—probably play a big role in many hydrogen-mediated metal failures.

"Anytime that atomic hydrogen is produced in the presence of H_2S," Walch reported, "embrittlement of sensitive materials should be expected." She cited a report concluding that for high-strength steels used in the oil industry, embrittlement could begin at H_2S concentrations as low or lower than those "that are found in the environment where there are lots of SRBs," she told SCIENCE NEWS. Moreover, Walch points out, bacteria produce a lot of hydrogen.

For hydrogen problems to occur, *atomic* hydrogen must be absorbed by a metal surface. Once a film of hydrogen forms on metal, explains Walch, individual hydrogen atoms in it will attempt to combine with each other. Those that do, forming hydrogen gas (H_2), quickly move away from the metal. But when there's sulfide present, this reaction is poisoned," she says. Since this leaves higher concentrations of hydrogen on the metal, it increases the chance they will be absorbed.

In a recent experiment where an anaerobic hydrogen-producing bacterium was grown on titanium, Walch found that metals would absorb microbe-generated hydrogen. Followup research is now focusing on mixed cultures of bacteria that contain hydrogen-consuming species.

Though metals tend to show a lower affinity for hydrogen than do bacteria, Walch notes that in experiments where she let two species of microbes with different affinities for hydrogen compete for the nutrient, the less aggressive did not lose out: It competed successfully by attaching itself directly to the hydrogen producer. "Similarly," she says, "a metal may compete effectively for hydrogen if the bacteria producing it are attached directly to the [metal's] surface."

Powerplants: When bigger isn't better

Biocorrosion of cooling-water systems in large electricity generating plants appears to be a growing problem. Materials engineers are now finding that contrary to good engineering practice, pipes and tanks that had been filled with water to test for leaks are not always drained and thoroughly dried at the completion of those tests.

Meryl Bibb of the Electricity Supply Commission in Johannesburg, South Africa, reported on one case where an inch-thick pipe developed a 20-millimeter diameter perforation only six months after a powerplant's startup. Though the pipe had been lined with polyamide epoxy to protect the metal from the corrosive ravages of water and 'bugs,' an inspection showed bacteria ate right through the epoxy to set up hard mounds protecting their colony on the metal surface below. A pigment in the epoxy appears to have provided a gourmet meal for those bacteria. Once the lining was breached, other microbes moved in, including the infamous, corrosion-fostering *Desulfovibrio*. (see p. 43).

Bibb says biocorrosion is more of a problem in newer plants constructed since 1975. And she attributes that to their size; they are up to 9 times larger than their predecessors. The bigger the plant, the longer the lag — and microbial-incubation period — between leak testing and plant startup.

Daniel Pope of Rensselaer Polytechnic Institute in Troy, N.Y., noted that U.S. plants appear to be suffering similar problems, and for the same reasons. Ironically, he notes, the stainless steels used extensively throughout U.S. nuclear plants are among the most susceptible to this biocorrosion. Based on this finding, he and colleague David Duquette are now conducting a biocorrosion survey of nuclear plants for the Electric Power Research Institute in Palo Alto, Calif.

Biocorrosion: Widespread vulnerability

In a biocorrosion research survey last year, Daniel Pope and David Duquette of Rensselaer Polytechnic Institute concluded "that every alloy system — with the possible exception of nickel-chromium and titanium — seems to show at least some [vulnerability] to biocorrosion," Duquette says. The survey was done for the Materials Technology Institute in Columbus, Ohio.

Despite titanium's superior biocorrosion resistance, Pope notes, it isn't much of an alternative to stainless steel, owing to its high cost and relatively poor heat-exchange characteristics. One possible alternative that's caught Pope's eye is a type of brass called "admiralty" brass. In hopes of verifying its apparent low vulnerability, he and Duquette are planning a survey of fossil-fueled powerplants that have employed the metal.

When stronger iron is weaker

At the University of Manchester Corrosion Protection Center in England, a group has been studying cast-iron piping buried in soil (used for such things as water mains). Their work has shown that gray iron (the garden-variety cast iron used extensively until ductile iron came on the scene in the 1960s) and the far-stronger ductile cast iron suffer somewhat equally from bacterial-enhanced corrosion. However, their performance, once degraded, can differ notably.

One reason, explains group leader Roger King, is that the graphite contained in the two cast irons differs morphologically. In gray iron, the graphite exists as flakes, whereas the graphite in ductile iron is spheroidal. As a result, when gray iron corrodes, the imbedded flake matrix of graphite often traps and binds corrosion products in place. If this piping is undisturbed, it may continue to function, even after heavily corroded, because its graphite flakes serve as natural braces. The spheroidal structure of the graphite in the ductile iron offers no comparable support. Therefore, when ductile iron corrodes, it just crumbles and falls apart, he says. A second reason ductile iron tends not to hold up as well under comparable biocorrosion attack, King says, is that because of their superior strength, ductile-iron pipes tend to be made thinner. And if both irons are equally suspectible to corrosion, obviously the thinner metal fails first.

Of rolls, welds and algae

Even production techniques appear to affect a metal's relative sensitivity to biocorrosion, according to chemist Chitta Ranjan Das of Ravenshaw College in Cuttack, India. In studies where steel samples were immersed in seawater containing two species of blue-green algae and one red alga native to the Sea of Bengal, mild (regular) steel corroded much faster than did stainless steel, and "cold-rolled metals corroded much faster than hot-rolled samples," Das reports. Though all the metals succumbed to corrosion in the control environment — seawater without algae—they did so far more slowly.

In all metals, corrosion first occurred at welds. And again, Das says, how a weld had been made appeared to affect vulnerability, "with gas-welded samples corroding much faster than electrical arc-welded samples."