Chapter 22

Graphitic Corrosion

Locations

Feedwater pumps, water supply lines, valves, and other components made of cast irons (containing graphite) are attacked. Because cast irons are used mainly in preboiler regions, attack is found primarily in water-pretreatment and -transport equipment.

General Description

Graphitic corrosion is possible only in structures composed of cast irons containing graphite particles. Susceptible cast irons are nodular, malleable, and gray. Although frequently considered immune to graphitic corrosion, nodular cast iron and malleable iron are often corroded. Gray cast iron is more widely used and has more dramatic and recognizable corrosion characteristics than other cast irons.

A galvanic effect occurs between graphite particles embedded in the casting and the surrounding metal matrix when mildly aggressive water contacts surfaces. The graphite is cathodic to the adjacent metal. The metal portion of the casting corrodes. Eventually the casting is converted to rust containing graphite particles. Corrosion is accelerated if waters are mildly acidic, have high conductivity, are soft, and/or contain high concentrations of aggressive anion such as sulfate.

Figure 22.1 Pump impeller severely attacked by graphitic corrosion. Material of the impeller is gray cast iron. Note the gray areas on both internal and external surfaces where the metal has been converted to rust and graphite.

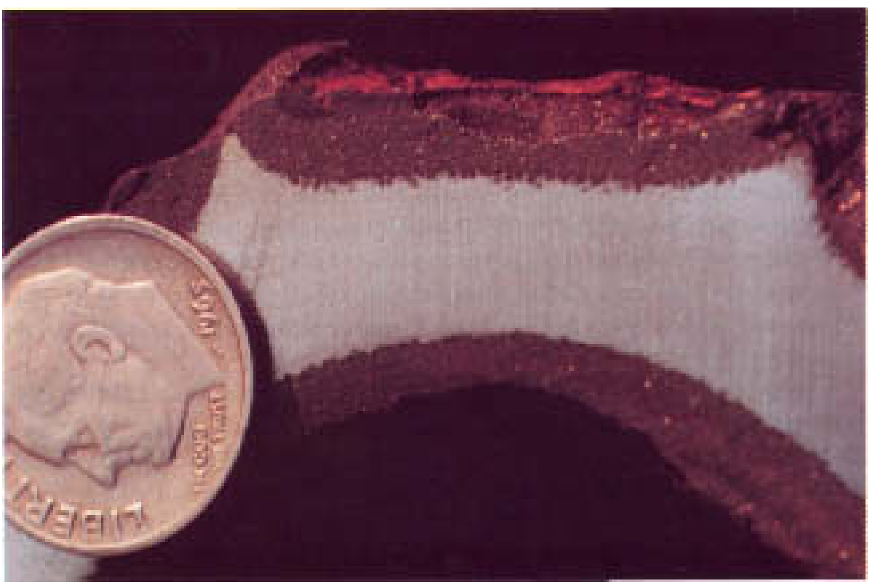

Figure 22.2 Note how uniformly metal is converted to corrosion product. Impeller vanes were lost in service because the graphitically corroded metal is brittle.

Critical Factors

Graphitic corrosion usually progresses slowly, taking many months or even years to produce significant attack. As pH decreases, attack quickens. Stagnant conditions promote attack, especially when waters contain high sulfate concentrations. Much attack occurs during idle periods. If turbulence is pronounced, (e.g., in pumps), corrosion products may be dislodged, also accelerating wastage.

Identification

Cast iron is converted to a soft mixture of iron oxides and graphite (Figs. 22.1 and 22.2). Pieces of corrosion product smudge hands and can be used to mark paper, just as if the corroded material were lead in a pencil (Fig. 22.3). Attack is often uniform, with all exposed surfaces corroded to roughly the same depth (Figs. 22.4 and 22.5). If localized deposits are present, especially those containing sulfate and chloride or other acidic species, corrosion may be confined to pockets. When attack is severe or prolonged, the entire component is converted to corrosion product. Surface contour and appearance are often preserved. Attack is usually not apparent until surfaces are probed or stressed.

Corroded areas can be broken with bare hands or by gentle taps with a hard implement. Craters can be dug in the soft, black corrosion product. Probing with a knife point can reveal the depth of penetration.

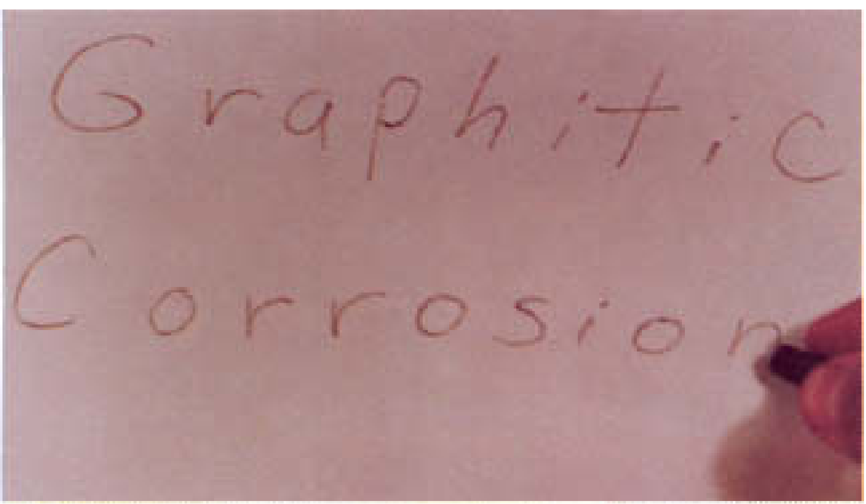

Figure 22.3 Fragment of graphitically corroded, gray cast iron pipe is used to write on paper, as if it were a lead pencil. The corrosion product is graphite flakes intermixed with rust.

Figure 22.4 Graphitically corroded valve butterfly. Original surface contours are preserved. Edges, which were completely converted to brittle corrosion product, have broken.

Figure 22.5 Severe graphitic corrosion of a gray cast iron feedwater-pump impeller. Patches of corrosion product have cracked and spalled, revealing uniform general wastage. Note the fracture in the impeller vane.

Elimination

Attack is reduced by alloy substitution, chemical treatment, and/or operational changes. Alloy substitution entirely eliminates graphitic corrosion if the corroded cast iron is replaced with alloys containing no graphite. The substitute alloy choice is dictated by requirements unique to each environment.

Raising water pH to neutral or slightly alkaline levels decreases attack, especially if relatively high concentrations of aggressive anions such as chloride and sulfate are present. The judicious use of chemical inhibitors may minimize deposits. When water flow is slight, such as during prolonged shutdowns and lengthy idle periods, attack increases. Stagnant conditions promote graphitic corrosion and should be avoided.

Cautions

Only cast irons containing graphite can corrode graphitically. Because of microstructural differences in graphite particle size and distribution, as well as other differences in alloy composition, attack is usually worst on gray cast irons.

Although pipes and other components may be severely corroded, they may not fail. The corrosion product has some mechanical strength, but is brittle. If corroded components are stressed, failure may occur catastrophically.

CASE HISTORY 22.1

Industry:	Food processing
Specimen Location:	Feedwater pump
Specimen Orientation:	Horizontal
Years in Service:	5
Water-Treatment Program:	Phosphate
Drum Pressure:	600 psi (4.1 MPa)
Tube Specifications:	8 in. (20.3 cm) diameter, 5 vanes, gray cast iron
Fuel:	Natural gas

A small feedwater-pump impeller was removed during a scheduled maintenance outage. The entire impeller surface was converted into soft, black corrosion products. In some areas, no trace of the original impeller alloy was left. Vane tips were totally converted to corrosion product. Vanes were cracked, and pieces of the corrosion product were dislodged, producing irregular contours (Fig. 22.5).

The impeller had been used intermittently, with greater than 50% idle time in the previous 2 years.