Chapter

5

Chelant Corrosion

Locations

The steam drum is the area of the boiler most frequently affected by chelant corrosion. Steam-separation equipment, especially equipment designed to separate steam by centrifugal means, is most susceptible to this type of corrosion. Chelant corrosion may also occur in feedwater distribution lines, in the economizer, on the ends of downcomer tubes, and in regions of high heat flux in water-cooled tubes. Copper and copper-alloy impellers of feedwater pumps may also corrode if exposed to chelating agents.

General Description

Concentrated chelants may attack magnetite according to the following reaction:

$$Fe_3O_4 + Fe + 8H^+ + 4 \text{ chelant} \longrightarrow 4Fe(II) \text{ chelant} + 4H_2O$$

Surfaces attacked by chelants are typically very smooth and featureless. In situations where there is sufficient fluid velocity, the surfaces may have a smoothly rolling contour marked by "comet tails" and horseshoe-shaped depressions (Fig. 5.1). These features are aligned with the direction of flow. The metal surface will be uniformly covered with a submicroscopic film of

Figure 5.1 Comet-tail and horseshoe-shaped depressions.

either dull or glassy black material. A surface under active attack will be free of deposits and corrosion products; they will already have been chelated.

Occasionally, when excessively high levels of oxygen are present, the appearance of metal loss is altered. The surface under attack retains sharply defined islands of intact metal surrounded by a smooth plain of

Figure 5.2 Chelant corrosion altered by the presence of excessive oxygen.

metal loss (Fig. 5.2). Some observers have reported that attack by chelants has given a jagged roughness, similar to that resulting from attack by a strong acid.

Critical Factors

Chelant corrosion can occur under a variety of circumstances. Overfeed of chelant is a frequently cited cause of chelant corrosion. However, at recommended residual levels of chelant, corrosion is possible in regions where a concentration mechanism is operating. The principal, and perhaps only, mechanism by which chelants are concentrated is by evaporation. Hence, chelant corrosion may occur where departure from nucleate boiling (DNB) occurs (Fig. 5.3).

Chelant corrosion of separation equipment in the steam drum, which does not contain heat-transfer surfaces, is apparently related to high fluid velocities. This type of corrosion is especially sensitive to the erosive effects of high-velocity fluids, and is sometimes encountered where these exist, even in the absence of heat transfer. Excessive levels of dissolved oxygen seem to act synergistically with excessive levels of chelant to produce jagged metal-surface contours.

Identification

Chelant corrosion can be visually identified if affected equipment is accessible. When access is very limited, as is generally the case with tubes,

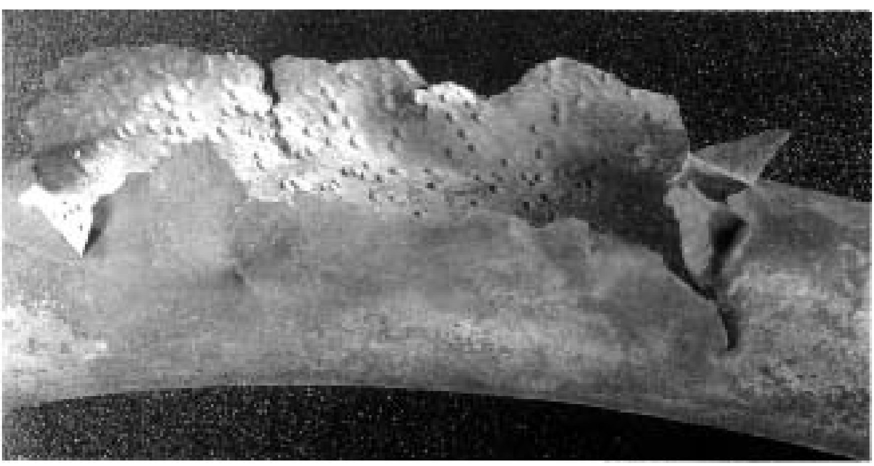

Figure 5.3 Tube rupture after severe metal loss by chelant corrosion. *(Courtesy of National Association of Corrosion Engineers.)*

nondestructive testing techniques such as ultrasonic testing may be used for identification.

Steam drum internals are particularly susceptible to chelant corrosion. Severe cases of corrosion have reduced cyclone separator cans to lacelike remnants.

Elimination

Close control of chelant and dissolved-oxygen levels is imperative. In order to eliminate chelant corrosion, certain actions can be taken.

First, special care must be exercised under conditions of inconsistent feedwater quality and when chelants are used in a dirty boiler. Second, elimination of hot spots in the firebox will prevent chelant corrosion of water-cooled tubes. Hot spots are frequently caused by improper boiler operation, improper boiler maintenance, and design deficiencies. Excessive overfiring or underfiring, misadjusted burners, change of fuel, gas channeling, excessive blowdown, and dislodged refractory have all been linked to the creation of hot spots as well. Many cases of chelant corrosion can be reduced in severity or eliminated altogether by reducing fluid velocity and eliminating turbulent flow.

Cautions

Chelant corrosion can give a smooth, featureless contour to metal surfaces. This feature, coupled with the fact that chelant-corroded metals typically have a black, passive appearance, masks the fact that active corrosion is occurring. In these cases, thickness measurements of suspect areas may reveal a problem.

Simple erosion by high-velocity steam or water may also yield an appearance that closely resembles that of corrosion by chelants.

Every effort should be made to avoid exposing copper-based alloys to chelants.

Related Problems

See also Chap. 7, "Low-pH Corrosion during Acid Cleaning," and Chap. 17, "Erosion."

CASE HISTORY 5.1

Industry:	Steel
Specimen Location:	Wall tube at bottom waterwall header
Specimen Orientation:	Vertical
Years in Service:	14
Water-Treatment Program:	Chelant
Drum Pressure:	900 psi (6.2 MPa)
Tube Specification:	2½ in. (6.3 cm) outer diameter
Fuel:	No. 6 oil and various waste gases

Failure of a section adjacent to the tube, illustrated in Fig. 5.4, occurred during hydrotesting. Severe internal wastage was confined to 6 to 9 in. (15.2 to 22.9 cm) of tube length in each of four adjacent tubes. Metal loss within the affected region varied. In areas of severe metal loss the appearance was smooth and wavelike. Discrete, isolated pits were evident in areas of moderate metal loss.

The highly localized attack on this section illustrates the importance of velocity and turbulence in an erosion-corrosion process involving chelants. Metal loss is severe in regions of turbulence at the inlet end of the tube from the header. The attack moderates with distance along the tube, until it ceases altogether where laminar flow is established. The chelant alone was not sufficiently aggressive to cause corrosion. Rather, metal loss resulted from the synergistic interaction of the chelant with localized turbulence.

Figure 5.4 Chelant corrosion on internal surface of inlet end.

CASE HISTORY 5.2

Industry:	Steel
Specimen Location:	Wall tube
Specimen Orientation:	Vertical bend
Years in Service:	25
Water-Treatment Program:	Chelant
Drum Pressure:	800 psi (5.5 MPa)
Tube Specifications:	3 in. (7.6 cm) outer diameter
Fuel:	Blast-furnace gas

The massive rupture of the wall tube (Fig. 5.3) was the first to occur in the boiler. The edges of the rupture are very thin, and a population of horseshoe-shaped depressions oriented in the direction of flow can be seen along the wasted internal surface. Microstructural examinations revealed that overheating had not occurred.

The rupture occurred on the cold side of the tube. The insulation installed to protect the cold side of this tube apparently had been dislodged by steam impingement from a leaking superheater tube. Hot furnace gases that reached the unprotected back side of the tube caused unstable film boiling and concentration of chelant from the boiler water.

The combination of concentrated chelant and fluid velocity caused the thinning of the internal surface apparent in Fig. 5.3. Thinning of the tube wall in this manner continued until stresses imposed by normal internal pressure exceeded the tensile strength of the thinned tube wall.

CASE HISTORY 5.3

Industry:	Chemical process
Specimen Location:	Feedwater-pump impeller
Specimen Orientation:	Vertical
Years in Service:	3
Water-Treatment Program:	Chelant
Tube Specifications:	8 in. (20.3 cm) outer diameter
Tube material:	Bronze

This impeller, illustrated in Fig. 5.5, was removed from the fifth stage of a feedwater pump. Broad areas of general wastage are apparent. Areas of metal loss are confined principally to regions of high turbulence such as the vane edges and discharge throat. Horseshoe-shaped depressions are visible in some regions.

Figure 5.5 Chelant corrosion on feedwater pump.

Close examination of wasted surfaces under a low-power stereoscopic microscope revealed dendrites and other microstructural features of the casting. Chelants are aggressive toward copper and copper-based alloys and should be fed well downstream of copper-alloy impellers.

CASE HISTORY 5.4

Industry:	Brewing
Specimen Location:	Steam-drum end of downcomer tubes
Specimen Orientation:	10 to 15° from vertical
Years in Service:	35
Water-Treatment Program:	Chelant
Drum Pressure:	485 psi (3.3 MPa)
Tube Specifications:	2½ in. (6.3 cm) outer diameter

Figure 5.6 illustrates the appearance of the internal surfaces of 12 adjacent downcomer tubes that have suffered severe internal corrosion. Although the same water-treatment program had been utilized for this boiler for 17 years, this corrosion occurred within a period of 7 months.

The affected tubes were located at one end of the boiler, within 9 in. (22.9 cm) of the feedwater line in the steam drum. It is surmised that feedwater was short-circuiting through the affected area.

Oxygen pitting was present along the waterline throughout the steam

Figure 5.6 Internal surface of downcomer tube.

drum, and on the steam-separation canisters. This is evidence that excessive levels of dissolved oxygen were present in the feedwater. The excessive oxygen levels, coupled with the presence of the chelant, resulted in the corrosion observed. The metal loss produced smooth, rolling, wavelike surface contours and islands of intact metal in affected areas (Fig. 5.7).

Figure 5.7 Internal surface of downcomer tube showing oxygen-assisted chelant corrosion.

The entire internal surface was lightly covered with deposits and iron oxides. The corroded metal was covered with a shiny black film under these deposits and iron oxides. The layer of iron oxides and deposits covering corroded surfaces reveals that corrosion had not been active recently, and therefore was not continuous, but intermittent.

This type of failure can be prevented by gaining control of dissolved oxygen. Preventing short-circuiting of the feedwater is also a solution to this type of corrosion.